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Editors

Anming Zhang

Brent D. Bowen

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## ABOUT THE EDITORS

DR. ANMING ZHANG, the Acting Head of the Department of Economics and Finance at City University of Hong Kong, joined the City as an associate professor in 1996 after teaching at University of Victoria, Canada, for six years. He received a BSc from Shanghai Jiao Tong University, MSc and PhD (1990, Economics and Business Admin.) from University of British Columbia. Dr. Zhang has published more than 20 research papers in the areas of industrial organization, international trade, and transportation. He received the Yokohama Special Prize for an Outstanding Young Researcher, awarded at the 7<sup>th</sup> World Conference on Transportation Research (WCTR), Sydney, Australia, July 1995. He won again the Overall Best Paper award (with Tae Oum and Yimin Zhang) at the 8<sup>th</sup> WCTR, Antwerp, Belgium, July 1998. Dr. Zhang has also done extensive consultancy work for government and industry.

DR. BRENT D. BOWEN is Director and Professor, Aviation Institute, University of Nebraska at Omaha. He has been appointed as a Graduate Faculty of the University of Nebraska System-wide Graduate College. Bowen attained his Doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor, Advanced-Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment in collegiate aviation programs. He is also well published in areas related to effective teaching. His professional affiliations include the University Aviation Association, Council on Aviation Accreditation, World Aerospace Education Organization, International Air Transportation Research Group, Aerospace Education Association, Alpha Eta Rho International Aviation Fraternity, and the Nebraska Academy of Sciences. He also serves as program director and principal investigator of the National Aeronautics and Space Administration funded Nebraska Space Grant and EPSCoR Programs.

### ***ATRG President's Foreword***

The **Air Transport Research Group** of the WCTR Society was formally launched as a special interest group at the 7<sup>th</sup> Triennial WCTR in Sydney, Australia in 1995. Since then, our membership base has expanded rapidly, and includes nearly 600 active transportation researchers, policy-makers, industry executives, major corporations and research institutes from 28 countries. Our broad base of membership and their strong enthusiasm have pushed the group forward, to continuously initiate new events and projects which will benefit aviation industry and research communities worldwide.

It became a tradition that the ATRG holds an international conference at least once per year . As you know, the 1997 conference was held in Vancouver, Canada. Over 90 papers, panel discussions and invited speeches were presented. In 1998, the ATRG organized a consecutive stream of 14 aviation sessions at the 8<sup>th</sup> Triennial WCTR Conference (July 12-17: Antwerp). Again, on 19-21 July, 1998, the ATRG Symposium was organized and executed every successfully by Dr. Aisling Reynolds-Feighan of the University College of Dublin.

In 1999, the City University of Hong Kong has hosted the 3<sup>rd</sup> Annual ATRG Conference. Despite the delay in starting our conference sessions because of Typhoon Maggie, we were able to complete the two-day conference sessions and presentation of all of the papers. On behalf of the ATRG membership, I would like to thank Dr. Anming Zhang who organized the conference and his associates and assistants for their effort which were essential for the success of the conference. Our special thanks go to Professor Richard Ho, Dean of the School of Business and Economics of the University for the generous support for the conference. Many of us also enjoyed the technical visit to the new Hong Kong International Airport (Chep Lok Kok).

As you know, Professor Jaap de Wit and I look forward to welcoming you to University of Amsterdam on July 2-4, 2000 for the 4<sup>th</sup> Annual ATRG Conference.

As in the past, the Aviation Institute of the University of Nebraska at Omaha (Dr. Brent Bowen , Director of the Institute) has kindly agreed to publish the Proceedings of the 1999 ATRG Hong Kong Conference (being co-edited by Dr. Anming Zhang and Professor Brent Bowen). On behalf of the ATRG members, I would like to express my sincere appreciation to Professor Brent Bowen, Mary M. Schaffart and the staff of the Aviation Institute of University of Nebraska at Omaha for the effort to publish these ATRG proceedings. Also, I would like to thank and congratulate all authors of the papers for their fine contribution to the conferences and the Proceedings. Our special thanks are extended to Boeing Commercial Aviation – Marketing Group for the partial support for publication of this proceedings.

Finally, I would like to draw your attention to the ATRG newsletter and the ATRG website ([www.commerce.ubc.ca/atrg/](http://www.commerce.ubc.ca/atrg/)) which will keep you informed of the ATRG operations and forthcoming events. On behalf of the ATRG Networking Committee, I would appreciate it very much if you could suggest others to sign up the ATRG membership. Thank you for your attention.

**Tae H. Oum**  
**President, ATRG**

ATRG c/ o Prof. Tae H. Oum  
Faculty of Commerce and Business Administration,  
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Vancouver, B.C., V6T 1Z2Canada  
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**Dr. Anming Zhang  
Coordinator, Transportation Operations and Policy (TOP) Group  
Center for Competitiveness  
Acting Head, Department of Economics and Finance  
Faculty of Business  
City University of Hong Kong  
Phone: +852-2788-7342  
Fax: +852-2788-8806  
E-mail: EFANMING@cityu.edu.hk**

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The 1999 Conference contained 13 aviation and airport sessions. Over 40 research presentations were featured on topics pertaining to airports and aviation; these titles are listed on the ATRG website (<http://www.commerce.ubc.ca/atrg/>).

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Once again, on behalf of the Air Transport Research Group, the University of Nebraska at Omaha Aviation Institute has agreed to publish the Proceedings of the ATRG Conference in a four-volume monograph set.

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**A MODEL FOR MEASURING ECONOMIC EFFECTS OF  
BILATERAL AIR TRANSPORT LIBERALIZATION**

**by**

**David Gillen\*, Richard Harris\*\* and Tae Hoon Oum\*\*\***

The earlier version of this paper was presented at the International Colloquium on Air Transportation, Toulouse, France, November 17-19, 1998, and at the American Economics Association (AEA) Conference (January 3-6, 1999: New York). The authors are grateful to Michael O'Connor, Steven Lewis-Workman and Jonathan Harvey for their work on simulation programs, and also to Transport Canada for funding this research through a contract to HLB Inc.

\* University of California & Wilfrid Laurier University    dgillen@newton.berkeley.edu

\*\* Simon Fraser University    rharris@sfu.ca

\*\*\* University of British Columbia    tae.oum@commerce.ubc.ca

# **A MODEL FOR MEASURING ECONOMIC EFFECTS OF BILATERAL AIR TRANSPORT LIBERALIZATION**

David Gillen, Richard Harris, and Tae Hoon Oum

## **ABSTRACT**

In this paper, we develop a model with which allows us to measure not only the changes in equilibrium outcomes and welfare consequences of liberalizing a bilateral air transport agreement, but also the distribution of the gains and losses to carriers and consumers of each bilateral country and those of the third foreign countries. Our model also allows to measure the effects of changes in a bilateral agreement on the amount of traffic diversion between the direct bilateral routes and the indirect routes via a third country. We also provide an extension of our model to a case of oligopoly market outcome (Cournot Nash equilibrium). In our model, quality aspects are treated in the framework of hedonic price theory by specifying the quality-adjusted price (quantity) as a multiplication of the observed price (quantity) by the reciprocal quality index function (the quality index function).

Numerical simulations were conducted to measure the effects of changing the following major policy levers in a bilateral air transport agreement:

- Removing price regulation while retaining frequency and entry restrictions
- Removing price and entry regulation while retaining frequency restrictions
- Removing frequency regulations while retaining price and entry regulations
- Removing frequency and entry regulations while retaining price regulation
- Removing price and frequency regulations while retaining entry restriction
- Removing all price, frequency and entry regulations (de facto, open skies)

The application to the case of the Canada-Japan bilateral agreement show the following results:

- Frequency competition without freeing entry or price regulation neither increase airline profits nor improve consumer welfare. Frequency competition with entry freedom increases the welfare of the nation whose carrier enters the market, i.e., the nation with lower cost carriers.
- Pricing freedom with frequency regulation increases the welfare of the nation with a larger share of passengers on the bilateral markets more than other countries. The benefits of price competition becomes more than doubled if entry is also freed.
- Overall, allowing entry of new carriers increase the overall welfare the most, followed by the price freedom. Just the removal of frequency restrictions has the least effect on consumer welfare.
- The complete liberalization of pricing, frequency and entry leads to the welfare maximizing market outcome. Oligopoly solution (Cournot Nash equilibrium) increase carrier profits while reducing consumer surplus substantially.
- The effects of liberalization of price and frequency regulations on O-D traffic volume, carrier profits and consumer surpluses are greater when the model takes into account of the third country routing possibilities.

## **A MODEL FOR MEASURING ECONOMIC EFFECTS OF BILATERAL AIR TRANSPORT LIBERALIZATION**

### **1. Introduction**

Although telecommunications, financial and maritime services have been incorporated in the General Agreement on Trade in Services (GATS) being governed by the World Trade Organization (WTO), most of the commercial air transport issues are not incorporated in the GATS. For more than 50 years, the issues involving commercial rights on international air transport have been governed by the bilateral agreements between each pair of countries involved. The bilateral framework for negotiating commercial aviation rights was adopted at the 1944 Chicago Convention. The Bermuda Agreement, the first bilateral air treaty signed between the United States and the U.K. in 1946 (Bermuda I) has served as the legal framework for the future bilateral agreements to follow. Bermuda I introduced capacity regulation, designation of carriers and routes, and system requirements for fair and equal opportunity for carriers involved. This complex system of regulation of commercial air transport has come under increasing criticism and pressure during the last two decades.

Soon after the deregulation of their domestic air transport markets in 1978, the U.S. government turned their attention to liberalize the bilateral agreements with foreign countries<sup>1</sup>. By virtue of the sheer size of their domestic market and the strength of its carriers, the U.S. was able to impart a pro-competitive approach on a large number of nations. The U.S. government used the new liberal bilaterals as a means of putting pressure on some reluctant governments. The UK and Germany were pressured by expansion of air service between the U.S. and Belgium and The Netherlands. A new liberal agreement with South Korea put pressure on Japan. Also, the U.S. took advantage of 5th freedom rights in certain countries to circumvent restrictions in neighboring nations with more restrictive bilaterals. This liberal bilateral approach was successful. The "Open Skies" campaign which the U.S. government began in 1992 was stimulated by strong criticism of the restrictive terms of Bermuda II.<sup>2</sup> Although these U.S. initiatives and the general movements towards freer goods and services trade have been successful for liberalizing air transport system to and from the U.S., the system of bilateral agreements between countries remain entrenched in the international air transport system.

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<sup>1</sup> For a nearly comprehensive measurement of the effects of the U.S. domestic deregulation on air carriers and travelers, please refer to Morrison and Winston (1986).

<sup>2</sup> In 1977, the UK renounced the Bermuda Agreement. The Bermuda II Agreement was accepted by the US and the UK and was aimed at restructuring the air relationships that had developed after 1945. This agreement was, in many ways more restrictive than the agreement that preceded it and was never a model for US bilateral air transport agreements.

For the next decade or two, liberalization of international air transport markets will depend nearly entirely on bilateral negotiations between countries involved.

In any bilateral negotiation, including general trade negotiations, parties to a bilateral negotiations on air transport are concerned very much with who gains, who loses and what impact the proposed change in the bilateral might have on traffic diversion to third country routings. Both of the countries involved need to better understand the consequences on the consumers and carriers of each bilateral partner and of any third party foreign nations of the proposed changes to the rules and restrictions governing the air transport bilateral. Although bilateral negotiators would like to take account of these complex effects in making decisions, air transport researchers have not directed sufficient effort to develop models which allow one to measure these complex consequences of the bilateral air transport liberalization.

Two previous studies have developed measures of the welfare gains from international air transport liberalization. Street, Smith and Savage (1994) measure both the gains in cost efficiency and improvements in service quality that would be caused by introducing greater competition in the Australia's international air transport markets. This paper is close to the current paper in that it attempted to measure gains and losses from bilateral liberalization to the Australian carriers and consumers. They use conventional "triangle" analysis via perfect competition model while doing some *ad hoc* adjustments for quality of services including flight frequency. The equilibrium outcomes are computed without full iteration of the interactive nature of demand and supply functions. They show that liberalization does not always yield a net welfare gain to Australian economy although, by definition, it will increase the world's welfare.

In another study, Findlay, Hufbauer and Jaggi (1996) measured the potential cost savings to users from the Asia-Pacific regional open skies regime. They assumed that the gains are all in the form of airlines' cost savings, all of which are transferred to consumers through competition. On the basis of this coarse calculation they show that the cost savings to users of seven countries (Australia, Canada, Hong Kong, Japan, Korea, Malaysia and Singapore) alone is \$21.7 billion in 2010.

The purpose of this paper is to develop a model with which to assess the effects of changes in a bilateral air transport agreement governing the supply of air transport services on the distribution of benefits and costs to bilateral partner nations' carriers, consumers and foreign carriers and consumers. Our approach differs from the traditional benefit-cost analysis of policy alternatives. Our focus is in the distribution of benefits and costs to various stakeholders: consumers and carriers of each bilateral partners and of third countries<sup>3</sup> while cost-benefit methodology focus on measuring aggregate economic benefits and costs for a given nation or region. Since trade policy researchers have concentrated on the distribution of the impacts of change in trading rules across nations and on identifying the winners and losers, methodologically we borrow significantly from

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<sup>3</sup> Governments are also a major gainer or loser through changes in net tax/subsidy revenues particularly as indirect taxation is an important feature of the tax framework or industrial or subsidy policies are in place.

the literature on trade policy analysis. In particular, our main model is the monopolistic competition model adopted from Spence (1976), Dixit and Stiglitz (1977), Krugman (1980), and Harris (1984). We also extend our model to obtain the effects of a different market structure (i.e., oligopoly) on the distribution of the gains and losses of bilateral air transport liberalization.

## 2. Key Policy Levers in Bilateral Air Transport Liberalization

The key commercial rights to be negotiated in a bilateral air agreement are pricing, capacity (new entry, frequency and aircraft size), and carrier and route designations. Carrier and route designation form a barrier to competition in several ways. First, bilateral air treaties normally limit the number of carriers who can serve the bilateral markets. For example, most bilateral agreements allow one carrier from each country to serve markets between the two countries: e.g., Korean Air and Air Canada in the Canada-Korea bilateral markets. Second, the cities and/or airports a designated foreign carrier can serve are normally specified. For example, Air Canada can serve Kansai International Airport only from Vancouver or Toronto while Canadian is allowed to serve only Tokyo's Narita Airport and Nagoya. Third, most bilaterals do not allow the fifth freedom rights (beyond right) to foreign carriers.<sup>4</sup> Clearly, removal or relaxation of the carrier/route designation clause is likely to induce competitive entry by new carriers as well as encourage entry into new routes and/or airports by the existing carriers.

Pricing regulations in bilateral agreements usually take one of the following forms. First, all carriers may be required to use the IATA set fares. Second, when only one carrier from each country serves the market the bilateral agreement may require the two carriers to agree on a uniform price. The third option is the so-called "single-disapproval" pricing regime that allows for one of the two governments to disapprove a carrier's fare proposal. In this case, a carrier's proposed fares are usually disapproved by the foreign government. The fourth option is the "double disapproval" regime. Under this regime, both governments are required to agree in order to disapprove a carrier's proposed fares. Airlines will have nearly complete pricing freedom under the double disapproval regime. Naturally, removal or relaxation of the pricing regulation increases competition.

The seat capacity that the carriers of a country can offer in aggregate are usually restricted in bilateral agreements.<sup>5</sup> Although many bilateral agreements allow the tradeoff between frequency of services and aircraft size used, in many bilateral routes the cost

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<sup>4</sup> Fifth Freedom rights must be negotiated separately and must include the third country.

<sup>5</sup> The nature of the capacity controls to either carrier in a bilateral is important. Restrictive regimes require agreement between designated carriers and approval by both authorities. Canada has very restrictive capacity regimes in all areas except with the United Kingdom, Germany and the Netherlands. In its largest twelve international markets, Canadian government has the right to designate more than one carrier in eleven of them. This multiple designation benefit could be negated with overall cap on capacity in the case of Hong Kong, Japan and Australia, while in France and Italy there would need to be an agreement between the incumbent carriers. Canada has the right to designate additional carriers, without capacity restrictions for 3rd and 4th freedom services to the United Kingdom, Germany, Netherlands, Jamaica, Mexico and Trinidad.

characteristics and the need to offer near daily flights limit the aircraft choice practically to only one or two aircraft types. Therefore, for simplicity of our analysis we will analyze the effects of allowing frequency competition only. We choose the optimal aircraft type for each route based on the unit cost per passenger.

Although other factors including access to airport slots and facilities could influence competitive outcomes significantly in bilateral air transport markets, in this study we will examine only the effects of removing or relaxing the pricing, capacity and entry regulations on consumers and carriers of each country and for each nation.

### **3. Model Development and Estimation**

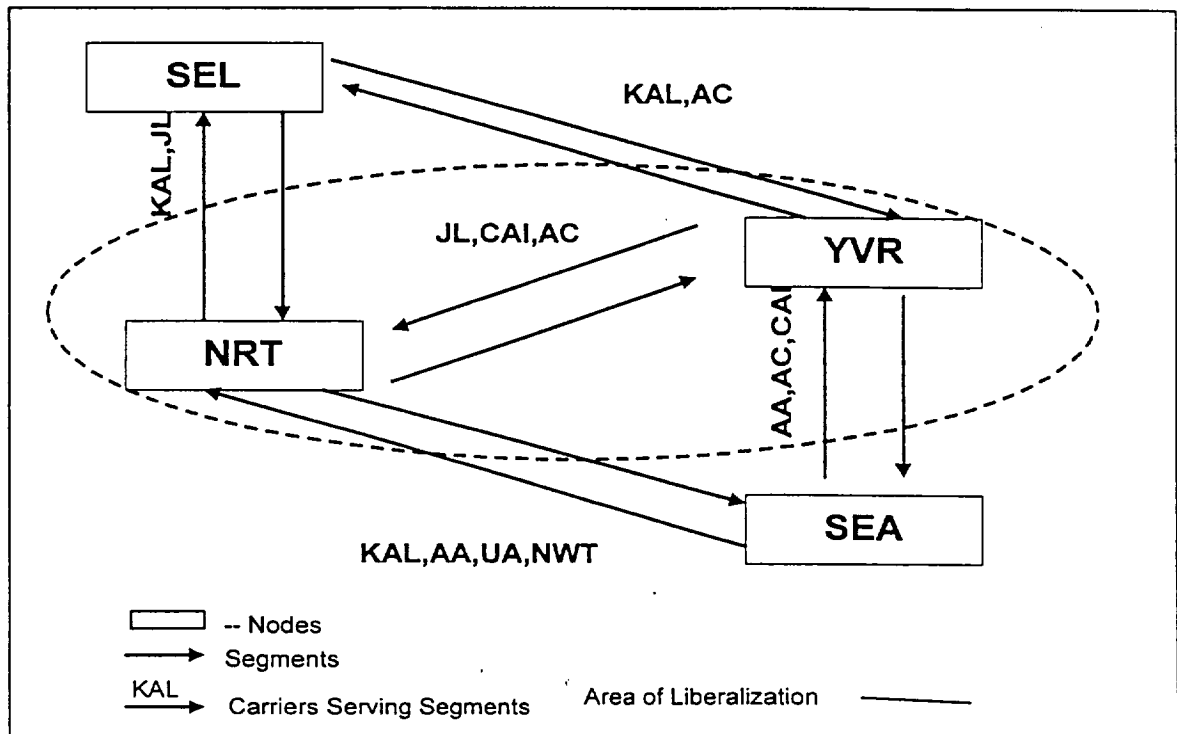
Our model uses a two-stage approach. In the first stage, the analytic foundations are laid by specifying demand and cost functions, market clearing conditions for demand and supply, and the equilibrium quantities and prices. In the second stage, numerical simulation is used to find each carrier's equilibrium traffic volume, price, and frequency.

Since air transport services are supplied in a network, the model must integrate all of the routing possibilities for each Origin-Destination (OD) market for all OD markets in the network. The starting point is to identify all of the OD market in the region, and then, map out the alternative routings for each of the OD pairs. In Figure 1, we illustrate a simplified version of such a network in the North Pacific. It is simplified to include only the OD traffic between Vancouver (YVR), Tokyo (NRT), Seattle (SEA) and Seoul (SEL). In this international network there are four countries, each country with a single airport, and three (3) potential OD markets in each country. For example, in Vancouver all originating traffic is assumed to be Vancouver based and destined for one of the three alternative destinations. Several alternative routes with several carriers serving a particular route can serve each OD market. Each route has one or more segments where a segment is a flight between two airports. Each carrier will carry passengers traveling on YVR-NRT, as well as passengers to YVR from other cities in Canada (Toronto-YYZ for example) and passengers traveling beyond NRT (to Seoul, for example). This means that passenger volume data must be captured separately by trip purpose, nationality, destination, fare class, route and carrier used.

An important question is what will happen to the characteristics of this network in response to a bilateral liberalization between Canada and Japan. While this liberalization will occur only to Japanese and Canada carriers and the network segments connecting Vancouver (YVR) and Tokyo (Narita or NRT), the evaluation of these effects will depend on the network wide demand and supply responses. For example, what portion of the traffic between Seoul (SEL) and YVR (or SEA and NRT) might be diverted through either NRT or YVR in response to the liberalization. Both the demand and supply specifications attempt to take into account these system wide interaction effects.

**Figure 1**

Illustrating Four Country North Pacific Air Transportation Network and Canada-Japan Liberalization



### 3.1 Characterization of Demand Model

The demand for air travel depends upon fares, frequencies, other service attributes, and choice of carriers. Current bilaterals place restrictions on some or all of these variables. As bilaterals are liberalized, consumers will be given increased choices of new and different carriers. The demand model must be capable of incorporating differentiated products to correctly capture changes in the level and quality of air services delivered by incumbent as well as new entrant carriers. One way of introducing preferences for differentiated services and products is to treat each of them as a different variety of services (imperfect substitutes). This stems from the idea that there are more products than characteristics, and re-bundling characteristics results in another product. Car, stereo, vacation, restaurant, wine and air trips are well-defined products. However, each of these products can and does have many varieties; American, Australian, Canadian and German wines, for example. The way in which one can handle this 'many varieties' for a product

can be handled by placing structure on the underlying preference functions thereby yielding manageable demand functions.

Armington (1969) introduced this idea of variety and nationally differentiated products into the trade literature. Our demand model follows this idea to derive demands for “differentiated” services (imperfect substitutes). This approach was chosen for a number of reasons. When a new carrier enters the market it represents a new ‘variety’ of an already traded service. This approach also allows for market size as well as carrier shares to change. In the air travel liberalization model, the services are alternative route-carrier combinations serving a given origin-destination pair. The basic model is amended to incorporate non-price (including quality) factors which can vary across route-carrier alternatives. This “Armington” specification of demand is chosen with the goal of measuring all of the benefits of changing the rules affecting the supply of international air travel services. We need to measure all of the changes to consumer benefits at the level of the route-carrier choice, aggregate flight segment, route aggregate, and O-D market.

The demand side distinguishes between aggregate OD demand, and demand for individual routes connecting an OD pair. For every OD pair there is a *home demand* aggregator at each end of the route (e.g., Canadian residents traveling to Japan) for each fare class. Each OD group can thus be thought of as an individual consumer with a [Marshallian] demand curve given by

$$Q=f(P) \quad \text{Equation 1}$$

$Q$  is an index of total passenger demand over the particular OD market, served by a number of route-carrier combinations indexed  $r=1, \dots, R$ . For simplicity, we refer to any given  $r$  simply as a route.  $P$  is the real price index for this route and is a function of the individual prices  $p_r$  for the route-carrier combination  $r$ .

$Q$  is referred to as the real quantity index of demand. It can also be interpreted as being measured in “utile” of *aggregate real air service*. Let  $q_r$  be the individual route demand measured in conventional passenger unit terms and let  $p_r$  be the route price. If we assume that the utility function generating  $Q$  is positive linear homogenous so that:

$$Q=U(q_1, \dots, q_R) \quad \text{Equation 2}$$

Then there exists an exact price index function  $P(p_1, \dots, p_R)$ , which is dual to  $U(\cdot)$ . It is convenient to work with the price index function rather than the utility or quantity index function.

Adopting the “Armington” assumption, in our model the route-carrier combinations (different variety of air services serving an OD pair) are regarded as imperfect substitutes as reflected in the following CES price index function  $P(\bullet)$ :



$$P(p_1, \dots, p_R) = \left[ \sum_{r=1}^R \delta_r p_r^{-\sigma} \right]^{-1/\sigma} \quad \text{Equation 3}$$

Here the  $\delta_r$  are the weights on individual routes  $r$  and  $\sigma$  is the Allen-Uzawa common elasticity of substitution between any two route pairs. Demand for route  $r$  given the level of aggregate  $Q$ , is given via Shephard's Lemma so that:<sup>6</sup>

$$q_r = \delta_r \left( \frac{p_r}{P} \right)^{-\sigma} Q \quad \text{Equation 4}$$

In consumer equilibrium total consumer expenditure in this OD market is given by:

$$E = \sum_{r=1}^R p_r q_r \quad \text{Equation 5}$$

By construction  $E=PQ$ ; actual expenditure on all routes is equal to the product of the price index and the aggregate real quantity index.

In our multi-country demand analysis, welfare as well as market shares are dependent on quality differences. This would include the effect of national preferences on their flag carriers. In order to accommodate differences across routes in quality characteristics, the linear quality model is used (which is closely related to the hedonic price approach to quality adjustment).<sup>7</sup> The quality index for route  $r$  with a vector of characteristics ' $x$ ' could be represented by quality function as  $a_r(f_r, t_r, \text{connections}, \text{national preference variable})$  where  $a_r$  is an increasing function in all variables corresponding to an increase in quality attributes such as frequency ( $f_r$ ). Our quality function,  $a_r(\cdot)$ , is specified as an iso-elastic function.

The basic model starts with a definition of quality adjusted units of real service with the quality function  $a_r(\cdot)$ .

$$q_r^* = a_r(x_r) q_r \quad \text{Equation 6}$$

The number  $q_r$  is referred to as the "unadjusted demand" or observed demand. In measurement terms it corresponds to the observable quantity of service  $r$  purchased by the consumer. In this case it corresponds to the number of passengers on a route in the relevant OD market. Higher  $a_r$  coefficients correspond to higher quality. Corresponding to the quality adjusted demand  $q^*$  there is a price  $p^*$ ; i.e., the price per unit of  $q^*$ .

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<sup>6</sup> Given a list of prices  $p_r$  on all routes, demand on route  $r$  is calculated in the following manner: compute the value of the aggregate price index  $P$  using equation 3; calculate the aggregate real quantity index  $Q$  using the aggregate demand curve (using equation 5); calculate individual route demands using equation 4.

<sup>7</sup> See Chapter 2, Tirole, Jean. Theory of Industrial Organization, for a complete exposition of this model.

Given the linearity of  $q_r^*$  in  $q_r$  it follows that:

$$p_r^* = (1/a_r(x_r))p_r \quad \text{Equation 7}$$

The quality units are chosen such that for a service with quality level  $a_r=1$ ,  $p_r=p_r^*$ . As the quality level rises for given  $p_r$ , the real price per unit of quality,  $p_r^*$  falls. Consumers actually buy the physical quantity  $q_r$  at price  $p_r$ , but from a utility point of view purchase  $q_r^*$  at price  $p_r^*$  per unit of quality-adjusted demand. This is the figure that affects the calculation of consumer surplus, our measure of benefits. Depending on the nature of the supply side of the model, consumers take both  $p_r$  and  $p_r^*$  as given and choose  $q_r^*$  and thus  $q_r$ .

If we apply the same approach for deriving unadjusted route demand functions to the case of quality-adjusted traffic volume, then the following expressions can be obtained.

$$Q^* = f(P^*) \quad \text{Equation 8}$$

$$P^* = \left[ \sum_{r=1}^R \delta_r p_r^{*- \sigma} \right]^{-1/\sigma} \quad \text{Equation 9}$$

$$q_r^* = \delta_r \left( \frac{p_r^*}{P^*} \right)^{-\sigma} Q^* \quad \text{Equation 10}$$

To empirically implement such a procedure it is necessary to have information on the quality coefficients  $a_r$  so that the real quality adjusted prices  $p_r^*$  can be calculated and substituted into the price index and demand functions. Having derived a quality-adjusted individual route demand via the same process outlined earlier, demand in observable units (passenger volumes) is given by:

$$q_r = \frac{\delta_r}{a_r} \left( \frac{p_r^*}{P^*} \right)^{-\sigma} Q^* \quad \text{Equation 11}$$

One of the benefits of this particular demand specification is that it allows explicitly for calculating consumers' welfare and demand consequences of adding new routes or reducing route choices in a given OD market and for quality changes on those routes. In effect any changes in quality or in the number of carriers in the market (the variety effect) are represented in terms of changes in real prices.

In equation 11 it is impossible to empirically distinguish between shifts in demand due to changes in  $\delta_r$  and changes in  $a_r$ . In order to identify the model we set all  $\delta_r$  equal to 1. The implication of this assumption is that if all routes offer the same quality and prices, then by assumption, the demand would be equal on all routes. Demand differences therefore must be attributed in the benchmark and counterfactuals to either quality or price

differences across routes. As a simple illustration, suppose there is a market where there are only two routes, so  $R = 2$  and both quality adjusted prices are equal to 1.0; thus demand on both routes is equal. Under these market conditions, the aggregate price index is given by:

$$P^*(2) = (\delta 1^{-\sigma} + \delta 1^{-\sigma})^{-1/\sigma} = (2\delta^{-\sigma})^{-1/\sigma} \quad \text{Equation 12}$$

Now suppose a new route is introduced that offers the same characteristics (price and non-price characteristics) as the previous routes so that its hedonic price is also unity, but now  $R = 3$ . In this case the new aggregate price index is given by:

$$P^*(3) = (\delta 1^{-\sigma} + \delta 1^{-\sigma} + \delta 1^{-\sigma})^{-1/\sigma} = (3\delta^{-\sigma})^{-1/\sigma} \quad \text{Equation 13}$$

We see in comparing these two equations that the real price index falls if  $\sigma > 1$ ; i.e. the elasticity of substitution between route/carriers exceeds unity. If  $\sigma = 2$ ,  $P^*(3)/P^*(2) = 0.81$ ; an increase from 2 to 3 route-carrier combinations is equivalent to a 19 percent reduction in the real price of aggregate travel. When substituted into the demand function the increase in real quality adjusted demand is approximately  $\eta^d \cdot \Delta P^*$ . In the case of exit of a carrier from the market, the adjustment would be in the opposite direction. We can think of there being a taste for variety; more variety even if not every one consumes, makes people better off. In effect, variety will be valued in its own right, (Dixit and Stiglitz, 1977).

This demand model is also explicitly structured to deal with the issue of inter-route substitution in a network context such as that outlined in the previous section. In Figure 1, for example, changes to the bilateral between Canada and Japan and liberalization of the of YVR-NRT market is likely to induce substitution between alternative routes connecting Japan and Canada, but passing through third countries. For example, a route such as SEA-NRT would be serviced by a U.S. carrier but with the liberalization the route SEA-YVR-NRT would draw some traffic. The extent of inter-route substitution in response to liberalization and its welfare consequences for consumers will depend on key parameters such as the carrier and route substitution elasticities and the relevant quality characteristics of competing routes.

### 3.2 Characterization of Supply Model

Our supply model captures changes in the carrier costs in the market that could be influenced by restrictions imposed by the bilateral agreements. Airlines may respond to changes in those restrictions (e.g., flight frequency) by supplying more or less and/or new services. To the extent that economies of traffic density exists, the changes in service frequency and traffic volumes will change the unit cost

In the demand model, any OD market may be served by a number of routes and each route is composed of one or more segments. In a network of multiple OD's, it is probable

that changes in one OD will affect passenger demands over the other OD's. For example, if higher frequencies are allowed between Canada and Japan not only will this OD market expand, but additional traffic may be garnered from passengers who are traveling to Korea via Japan. The flight segment YVR-NRT will carry more than simply the O-D traffic and this will affect costs through economies of traffic density. The base unit for the cost function will therefore be the flight segment. Once the segment costs are calculated it is possible to construct a route cost by aggregating the relevant segment costs. The total carrier costs are calculated as the sum of all passenger costs and segment costs.

In describing a carrier's costs we distinguish costs which vary by segment and those which vary by route. In many cases the source of cost differences will be in the airline system or station costs. For example, if carrier *i* were to extend its operation from point B to point C, when it was already in an AB market, the additional costs would include the increase in flight operating costs and passenger costs. However, since it is already serving airport B, the cost of adding an operation will be low. This is quite different from a case of entering an entirely new market. Clearly, both volume of passenger and flight frequency are important.

Therefore, we define a carrier's total cost for a segment as follows:

$$TC = vQ + wF \quad \text{Equation 14}$$

where *F* is segment frequency and *Q* is segment passenger demand. *v* and *w* are unit cost per passenger and unit cost per flight, respectively. Carrier load factors are calculated as  $z = (Q/F)/G$  where *G* is seats per plane. Average per-passenger segment cost, *u*, can be computed by dividing the total segment cost by the number of passengers. The approximate average cost per passenger is obtained by dividing the total block hour costs (flight costs) for the segment plus the total passenger costs by the number of segment passengers. Therefore, the (total) unit cost per passenger on flight segment can be written as follows:

$$u = TC/Q = wF/Q + v = (w/Gz) + v \quad \text{Equation 15}$$

The unit cost per passenger will change as the volume of passengers, flight frequency or load factors change.

The per-flight operating cost per segment (*w*) was computed using the block-hour operating cost (for each aircraft type) for the U.S. carriers available using FORM 41 data.<sup>8</sup> Since the block-hour costs on non-U.S. carriers were not available by aircraft type, the costs for American Airlines (AA) are adjusted for estimating the block-hour costs for foreign carriers. This involved taking account of the differential total factor productivity

<sup>8</sup> The cost data are taken from Aviation Daily, various issues. These figures are based on the information contained in the FORM 41 data series.

(TFP) and the aggregate input price index between AA and the carrier under our consideration. Table 1 lists the differential TFP and input price indices between the American Airlines and other carriers computed by Oum and Yu (1995). This information is used to estimate the block-hour costs for the carriers under consideration in this paper.

**Table 1: Productivity Index Table for Cost Calculations**

<b>Productivity and Price Indices - 1993</b>			
<b>American = 1.00</b>			
<b>Numeric Code</b>	<b>Airline</b>	<b>TFP</b>	<b>Price Index</b>
1	American	1.000	1.000
2	United	1.045	1.035
3	Delta	1.069	1.075
4	Northwest	1.124	1.036
5	US Airways	0.832	1.034
6	Continental	1.005	0.891
7	Air Canada	0.807	0.881
8	Canadian	0.860	0.911
9	Japan Air Lines	0.851	1.421
10	All Nippon	0.777	1.432
11	Singapore Airlines	0.958	0.813
12	Korean Air	0.988	0.781
13	Cathay Pacific	0.969	0.926
14	Qantas	0.875	0.897
15	Thai	0.647	0.520
16	Lufthansa	0.956	1.190
17	British Air	0.893	0.974
18	Air France	0.875	1.089
19	Alitalia	0.840	1.250
20	SAS	0.838	1.289
21	KLM	0.946	1.098*
22	Swissair	0.950	1.360*

The indirect cost per passenger ( $v$ ) was computed as follows. The total indirect cost for an airline was computed by subtracting the total flight costs from its total cost. The total indirect cost for a flight segment was estimated by allocating the carrier's total indirect costs in proportion to the revenue generated from that particular route segment. Then, the per-passenger indirect cost for a flight segment ( $v$ ) was computed by dividing the segment indirect cost by the segment passenger volume ( $Q$ ).

For the case of a two-segment route, the unit cost is obtained by adding the two segments' unit costs per passenger. The carrier profit from a route is then obtained by

taking the difference between the fare and the route's unit cost, and multiplying it by the route demand volume. In this way, load factors are endogenized in the model. This has important implications for dynamic efficiency effects. Entry affects costs in two ways. First, entry of a low cost carrier affects incumbents' costs by putting pressure on input prices and productivity. Second, it changes incumbents' passenger volume, which, in turn, changes their per-passenger segment costs by being at a different point on the economies of density curve.

#### **4. Alternative Scenarios and Construction of the Base Case**

The model was applied to the cases of Canada-Japan (Vancouver-Tokyo market), Canada-Germany (Toronto-Frankfurt market) and Canada-Australia market. This paper reports only the empirical results for the Canada-Japan case.

For each case, the following alternative scenarios are simulated and the equilibrium results are compared:

- (a) Base Case: price and capacity (frequency) regulated
- (b) Price regulation/capacity competition (with/without new entry)
- (c) Price competition/capacity regulation
- (d) Full competition (no restrictions on price, capacity or entry)

At first, the simulation results were obtained for each of the above scenarios under the assumptions of differentiated monopolistic competition and closed bilateral trade (no alternative routing via third countries). Later, the selected simulation experiments were conducted to examine the effects of an alternative market structure: oligopoly vs. monopolistic competition and with and without explicitly accounting for traffic diversion to third country routes.

##### ***The Base Case: Price, Entry and Capacity Regulated***

The key variables to describe the base case in an OD market are the airlines serving the market, type of aircraft being used, the passenger volume by airline, fares by airline, frequency by airline, travel time by airline and a carrier specific preference (nationality) factor. Most of these data are collected from a variety of sources such as Transport Canada and US Department of Transportation, ICAO, Official Airline Guide (OAG), travel agents and the airlines themselves.

The carrier specific preference factor is computed by calibrating the demand model to the base case data. The difference between the observed passenger volume for a route-carrier combination and the predicted demand, i.e., proportion of the traffic volume that cannot be explained by the route-carrier characteristics, is regarded as the carrier specific preference factor. Table 2 illustrates the type of input variables needed for calibration of demand.

**Table 2: Example Input Table for CALM Model**

<b>BASE CASE ROUTE/CARRIER CHARACTERISTICS</b>						
<b>Carrier Code</b>	<b>Plane Code</b>	<b>Type PAX</b>	<b>Fare</b>	<b>Frequency Code<sup>9</sup></b>	<b>Travel Time</b>	<b>National preference</b>
1	1	63,875	434.30	10	7.50	1.00
7	1	63,875	434.30	10	7.50	1.50

Based on the review of empirical studies and surveys on demand elasticities,<sup>9</sup> the demand parameters assumed to range between the upper and lower bound values listed in Table 3.

**Table 3: Demand Parameters Used**

<b>Demand Parameters</b>	<b>Probability Range*</b>		
	<b>Lower 10% Value</b>	<b>Median Value</b>	<b>Upper 10% Value</b>
Elasticity of Substitution	1.5	2.0	2.5
Elasticity of Demand with Respect to Frequency	0.05	0.10	0.20
Elasticity of Demand with Respect to Own Price	-0.075	-1.35	-2.0

\*This probability range corresponds to an eighty percent confidence interval.

## 5. Canada-Japan Results

The Canada-Japan market was and is still being tightly regulated by the current bilateral agreement. This agreement controls carrier and route designation (including point of origin and point of access), seat capacity of aircraft used, and prices (single disapproval).

In 1993, Canadian Airlines International (Canadian) and Japan Airlines (JAL) served Canada-Japan market. Canadian operated 8 flights per week between Vancouver (YVR) and Tokyo's Narita airport while JAL operated 7 passenger flights. Both carriers charged the median discount fare of C\$680 per one-way passenger. Canadian and JAL carried 99,720 and 88,050 passengers, respectively, in 1993. Based on our model Canadian made a profit of C\$24 million on this route while JAL made only about C\$2 million.<sup>10</sup>

<sup>9</sup> See Oum, Waters and Yong (1992) for a survey of transport demand elasticities, Oum, Gillen and Noble (1986) for estimates of elasticities of substitution, and Morrison and Winston for estimates of frequency elasticity of demand.

<sup>10</sup> Although an additional routing served by Canadian (Toronto – Narita) was included in our simulation, this paper reports the results on the Vancouver-Tokyo market only.

### ***Effects of Removing Frequency Regulation:***

The market equilibrium results for the case of frequency competition (while regulating price and entry) are reported in Table 4, Column 2 (Without Entry). Under this scenario both carriers maintain profitability, and total route demand is expected to increase by only 1 percent. However, relative to the base case this market outcome is less profitable for Canadian and slightly more profitable for JAL. The welfare gain to Japan is approximately \$2 million dollars while the welfare loss to Canada is approximately \$6 million dollars, making a combined net welfare loss of \$4 million. For Canadian, the reduction in profitability occurs because the bilateral change increases capacity at a rate that exceeds demand, pushing the segment load factor below 60 percent. This in turn has a negative impact on carrier costs and hence profitability. Canadian's position is further eroded by the observed carrier preference for Japanese carriers in the market.

Table 4, Column 3 (With Entry) reports the equilibrium results for the case of removing both frequency and entry regulations while maintaining price regulation. In this scenario, a new carrier, namely, Air Canada enters the market with six flights per week. At equilibrium, each incumbent carrier offers six flights per week. The relative cost efficiency of these carriers places Canadian Airlines International (CAI) as the most cost competitive (and thus most profitable), followed closely by Air Canada and Japan Airlines. The entry of a new carrier in this market has a significant impact on route traffic volume – a 37 percent increase over the case of frequency competition without entry. This scenario also produces positive welfare impacts relative to the no entry case. The gain in aggregate profits for carriers is combined with the gain in consumer benefits of approximately \$30 million to produce a total net welfare gain of \$61 million dollars. Since the Japanese passengers dominate the market, non-Canadians capture the majority of the gain in consumer benefits while Canada captures a majority of the carrier profits due to the entry of Air Canada.

### ***Effects of Removing Price Regulation:***

Table 5 exhibits the equilibrium results of price competition with frequency regulation. The results with and without entry regulation are contained in the table. The results with entry regulation, Column 2, show that CAI reduces price by more than 27 percent while JAL reduces it by 19 percent. JAL can attract an almost equal number of passengers while charging a substantially higher fare than CAI because Japanese passengers prefer to fly with JAL (a positive carrier specific factor). Consumers now, in part, capture the economic rents previously captured by the carriers. The net welfare effect is positive, with the consumer benefits slightly outweighing the reduction in carrier profits.

Column 3 (With Entry) of Table 5 reports the (equilibrium) results for the case of removing both price and entry regulations while keeping frequency regulation. The results show that the entry of a new carrier (Air Canada) is important not only for stimulating market demand, but also because it offers consumers a wider range of choice. Consumer benefits are far in excess of the scenario where frequency competition takes



place in the absence of price competition. It is also true that consumer benefits increase largely via a transfer of carrier profits; net welfare has more than doubled as compared to the case of price competition without removing frequency and entry regulations. Unlike the previous scenario, the distribution of benefits falls more heavily in favor of Canada because a Canadian carrier enters a profitable market. This is in stark contrast to the no entry case, where the Canadian carrier suffers and Canadian consumer benefits are much smaller.

#### ***Effects of Removing Regulations on Price, Frequency and Entry:***

This scenario is essentially the bilateral open-skies agreement that does not involve opening of the 5<sup>th</sup> freedom traffic rights. The simulation results are reported in Table 6. In this scenario, Air Canada enters the Vancouver- Tokyo market, and each of the three carriers would serve flights per week. The entry of a new carrier (Air Canada) makes the market significantly more competitive, and as a result, the equilibrium prices are significantly lower than the case with entry regulation. As a result of both entry and lower prices traffic volume would increase by about 50%. Furthermore, there would be a five-fold increase in the welfare gain to Canada because of the entry of Air Canada while Japan's welfare gain is limited to an increase from \$23 million to \$38 million.

#### ***Canada-Japan Outcome under an Oligopoly Market Structure***

Oligopoly firms can exercise market power by erecting entry barriers and charging substantial market-up over marginal cost. Oum, Zhang and Zhang (1993) have found that most airlines play a Cournot game in their markets. At the Cournot-Nash equilibrium an airline with a large market share can charge a substantial mark-up over and above their marginal costs.

Table 7 compares the equilibrium outcomes of the base case and the two cases of the price and frequency competition case (the case of monopolistic competition and the case of Cournot oligopoly). In these simulations we assume that the incumbents are successful in blocking entry of potential competitors. The aggregate gain to consumers is approximately \$32.7 million for the case of price and frequency competition without any oligopoly markup. With the imposition of the mark-up the consumer gain is reduced to \$13.0 million because of the increased prices and reduced volumes. The carriers' total profits increase over the no-mark-up case by \$9.33 million. The aggregate net welfare shrinks from \$38 million for the no-mark-up case to \$28.3 million for the oligopoly markup case.

#### ***Incorporation of the Aspects of Traffic Diversion to Third Country Routes:<sup>11</sup>***

As we discussed previously, a bilateral liberalization not only increases competition in the direct routes, but also induce those who are traveling via foreign cities to return to the

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<sup>11</sup> In a closely related work, Dresner and Oum (1998) investigates the effects of Canada's "facilitating" and US liberal bilateral air agreements on the share of visitors travelling directly to Canada, as opposed to transiting through the United States.

direct routes. The liberalization can improve the relative attractiveness of the direct flight as compared to travel via a third country point. For example, the liberalization of Canada-Japan bilateral agreement would induce the passengers traveling between Canada and Japan via a U.S. point to use the direct route. Furthermore, it would cause some of the U.S. and Japanese passengers traveling between the U.S. and Japan to route their travel via Canadian points. Intuitively, the effects of accounting for such traffic diversion in the model is expected to increase both carriers' and consumers' benefits. These added passengers benefit the airlines in two ways. First, they increase traffic density on the Vancouver – Tokyo route, and thus, reduce per-passenger cost. Second, the added demand increases the market clearing price slightly, further increasing revenue and profit margins.

Table 8 reports the simulation results for the case involving third country routing. For the Vancouver – Tokyo market, traffic diversion occurs when passengers who now fly between Vancouver and Narita through US gateways may consider a direct Vancouver routing. Our results show that the removal of price and frequency regulation in the Canada-Japan bilateral is likely to reduce the passengers who travel via Vancouver-Seattle-Tokyo (via Northwest) from 11,300 to 8,950 persons. Likewise, it will reduce those who travel via Vancouver-San Francisco-Tokyo (via United) from 7,520 to 5,520 persons. These translate into additional consumer benefits of approximately \$1 million dollars or 3 percent of the original benefits estimate. Similarly, both Canadian's and JAL's profit increases.

### *Summary Results on the Canada-Japan Case*

The simulation results on the Canada-Japan case can be summarized as follows:

- When price is regulated, frequency competition benefits both countries only if entry regulation is also removed. Frequency competition without freeing the entry neither increase airline profits nor improve consumer welfare.
- For the Canada-Japan case, frequency competition with entry freedom (when price is regulated) increases Canada's welfare more than Japan's because the new entrant is a Canadian carrier, Air Canada.
- When price regulation is removed while keeping frequency regulation intact, both carrier profits and consumer benefits increase substantially when frequency is regulated at reasonable level. The total consumer surplus increases more to Japanese passengers than to Canadian passengers because a large majority of the passengers on Vancouver-Tokyo segment are Japanese nationals. Needless to say, both consumer surplus and carrier profits would be significantly affected if frequency is regulated at wrong value.
- The benefits of price competition get more than doubled if entry is also freed. Although Air Canada is the only carrier expected to enter the market, the overall

welfare gain is greater for Japan than for Canada because of the dominance of Japanese passengers on Vancouver-Tokyo market.

- The complete liberalization of pricing, frequency and entry leads to the welfare maximizing market outcome.
- Oligopoly solution (Cournot Nash equilibrium) increase carrier profits substantially while reducing consumer surplus.
- The effects of liberalization of price and frequency regulations on O-D traffic volume, carrier profits and consumer surpluses are greater when the model takes into account of the third country routing possibilities.

## 6. Summary and Conclusion

In this study, we attempted to develop a model with which to measure the economic effects of liberalizing bilateral air agreements between two countries. Our model allows us to measure not only the changes in equilibrium outcomes and welfare consequences of liberalizing a bilateral air transport agreement, but also the distribution of the gains and losses to carriers and consumers of each bilateral country and those of the third foreign countries. In particular, our model allows to measure the effects of changes in a bilateral agreement on the amount of traffic diversion between the direct bilateral routes and the indirect routes via a third country. We also provide an extension of our model to a case of oligopoly market outcome (Cournot Nash equilibrium).

Since quality of services is important for determining air transport demands, costs and consumer welfare, our main model is developed by adapting the monopolistic competition model of Spence (1976) and Dixit and Stiglitz (1977) to the air transport situation. This allowed us to incorporate the attributes of service quality such as frequency of service, travel time, number of connections required to complete a travel, and national flag carrier preference factor in the demand model. We adopted the "Armington" assumption by specifying our Origin-Destination specific demand model in the CES form and thereby treating the 'route-carrier' combinations serving an Origin-Destination market as imperfect substitutes to each others. Quality aspects are treated in the framework of hedonic price theory by specifying the quality-adjusted price (quantity) as a multiplication of the observed price (quantity) by the reciprocal quality index function (the quality index function).

The total cost of a flight segment consists of the costs that vary with flight frequency and those that vary with number of passengers carried. This implies that our model allows the carriers to adjust their unit costs dynamically with the traffic density on the route segment.

Since it was not possible to obtain closed form expression for equilibrium solutions, numerical simulations were conducted to measure the effects of changing the following major policy levers in a bilateral air transport agreement:

- Removing price regulation while retaining frequency and entry restrictions
- Removing price and entry regulation while retaining frequency restrictions
- Removing frequency regulations while retaining price and entry regulations
- Removing frequency and entry regulations while retaining price regulation
- Removing price and frequency regulations while retaining entry restriction
- Removing all price, frequency and entry regulations (de facto, open skies)

Our model was applied to the cases of Canada-Japan, Canada-Germany, and Canada-Australia bilateral agreements. Although this paper reports the empirical results on the Canada-Japan bilateral case only, they are by and large consistent with those of the Canada-Germany and Canada-Australia cases.

Our key results can be summarized as follows:

- Frequency competition without freeing entry or price regulation neither increase airline profits nor improve consumer welfare. Frequency competition with entry freedom increases the welfare of the nation whose carrier enters the market, i.e., the nation with lower cost carriers
- Pricing freedom with frequency regulation increases the welfare of the nation with a larger share of passengers on the bilateral markets more than other countries. The benefits of pricing freedom are significantly affected by the regulated frequency of services. The benefits of price competition becomes more than doubled if entry is also freed.
- Overall, allowing entry of new carriers increase the overall welfare the most, followed by the price freedom. Just the removal of frequency restrictions has the least effect on consumer welfare.
- The complete liberalization of pricing, frequency and entry leads to the welfare maximizing market outcome.
- Oligopoly solution (Cournot Nash equilibrium) increase carrier profits while reducing consumer surplus substantially.
- The effects of liberalization of price and frequency regulations on O-D traffic volume, carrier profits and consumer surpluses are greater when the model takes into account of the third country routing possibilities.

Our current research attempted to measure the effects of liberalizing the bilateral agreement with a single country. We have not attempted to measure the effects when a country liberalizes its bilateral agreements with many countries as the U.S. government is pursuing. Extending our model to handle such a situation would not be straight forward, but it is an interesting avenue for future research.

Our analysis is also limited to measuring the effects on the producers and consumers of air transport services only, ignoring other benefits of bilateral air liberalization including the benefits to tourism sector. Certainly, there is a need to incorporate several related sectors including tourism in the analysis of air transport matters. However, use of a full general equilibrium model for air transport analysis may not be an effective avenue to pursue. Since air transport sector, especially each bilateral air transport market, is small relative to other sectors of the economy, it would be difficult to identify the effects of liberalization of a small number of bilateral agreements within a full general equilibrium model because those small effects are likely to be buried in the changes in larger economic sectors.

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**Table 4: Vancouver – Tokyo: Frequency Competition /Price Regulation**

	Base Case*	No Entry	With Entry
<b>Median Discount Fare (One Way in \$)</b>			
Canadian	680	680	680
Japan Air Lines	680	680	680
Air Canada			680
<b>Average Weekly Frequency</b>			
Canadian	8	8	6
Japan Air Lines	7	8	6
Air Canada			6
<b>Demand (Thousands of One Way Passengers)</b>			
Canadian	99.7	87.6	80.5
Japan Air Lines	88.1	102.2	89.2
Air Canada			89.2
Total Demand	187.8	189.8	258.9
<b>Profits (Millions of \$)</b>			
Canadian	23.9	17.9	21.8
Japan Air Lines	2.0	3.2	10.4
Air Canada			30.2
Total Profit	25.9	21.1	62.4
<b>Welfare Impacts*</b>			
Consumer Benefits - aggregate (Millions of \$)		1.1	29.9
Consumer Benefits to Canada (Millions of \$)		0.3	8.9
Consumer Benefits to others (Millions of \$)		0.8	20.7
<b>Producer Benefits (Millions of \$)</b>			
Chg. in Canadian Profit (Millions of \$)		-6.1	-4.5
Chg. in Japan Airlines Profit (Millions of \$)		1.2	5.4
Chg. in Air Canada Profit (Millions of \$)			30.1
Chg. in Total Profit		-4.9	31.0
Aggregate Welfare Gain (Millions of \$)		-3.7	60.6
Aggregate Welfare Gain to Canada (Millions of \$)		-5.7	34.5
Aggregate Welfare Gain to others (Millions of \$)		2.0	26.1

\*All results reported in 1993 Canadian dollars.



**Table 5: Price Competition /Frequency Regulation**

**Vancouver – Tokyo**  
**(Frequency regulated at 7 flights per week)**

	Base Case*	No Entry	With Entry
<b>Median Discount Fare (One Way in \$)</b>			
Canadian	680	546	505
Japan Air Lines	680	601	560
Air Canada			513
<b>Demand (Thousands of One Way Passengers)</b>			
Canadian	99.7	115.6	115.5
Japan Air Lines	88.1	115.7	115.4
Air Canada			115.5
Total Demand	187.8	231.3	346.5
<b>Profits (Millions of \$)</b>			
Canadian	23.9	25.6	19.5
Japan Air Lines	2.0	13.3	5.8
Air Canada			19.0
Total Profit	25.9	38.9	44.3
<b>Welfare Impacts*</b>			
Consumer Benefits - aggregate (Millions of \$)		21.8	50.3
Consumer Benefits to Canada (Millions of \$)		6.6	15.4
Consumer Benefits to others (Millions of \$)		15.3	34.5
<b>Producer Benefits (Millions of \$)</b>			
Chg. in Canadian Profit (Millions of \$)		-0.7	-4.4
Chg. in Japan Airlines Profit (Millions of \$)		8.4	3.8
Chg. in Air Canada Profit (Millions of \$)			19.0
Chg. in Total Profit		7.8	18.0
Aggregate Welfare Gain (Millions of \$)		29.7	68.2
Aggregate Welfare Gain to Canada (Millions of \$)		5.9	30.0
Aggregate Welfare Gain to others (Millions of \$)		23.8	38.3

\*All results reported in 1993 Canadian dollars.

**Table 6: Price and Frequency Competition**  
(Vancouver – Tokyo)

<b>Final Equilibrium</b>	<b>Base Case</b>	<b>Without Entry</b>	<b>With Entry Freedom</b>
Median Discount Fare (One Way in \$)			
Canadian	680	494	505
Japan Air Lines	680	549	560
Air Canada			513
Frequency			
Canadian	8	8	7
Japan Airlines	7	8	7
Air Canada			7
Demand (Thousands of One Way Passengers)			
Canadian	99.7	131.9	115.5
Japan Air Lines	88.1	131.9	115.4
Air Canada			115.5
Total Demand	187.8	263.8	346.5
Profits (Millions of \$)			
Canadian	23.9	23.3	19.5
Japan Air Lines	2.0	8.5	5.8
Air Canada			19.6
Total Profit	25.9	31.8	44.2
<b>Welfare Impacts</b>			
Consumer Benefits - aggregate (Millions of \$)		32.7	50.3
Consumer Benefits to Canada (Millions of \$)		9.8	15.4
Consumer Benefits to others (Millions of \$)		22.9	34.5
Producer Benefits (Millions of \$)			
Chg. in Canadian Profit (Millions of \$)		-0.6	-4.4
Chg. in Japan Airlines Profit (Millions of \$)		6.6	3.8
Chg. in Air Canada Profit (Millions of \$)			19.0
Chg. in Total Profit		5.9	18.0
Aggregate Welfare Gain (Millions of \$)		38.6	68.2
Aggregate Welfare Gain to Canada (Millions of \$)		9.2	30.0
Aggregate Welfare Gain to others (Millions of \$)		28.8	38.3

\*All results reported in 1993 Canadian dollars.

**Table 7: Price/Frequency Competition with and without Oligopoly Markup  
(Vancouver – Tokyo)**

	Base Case	without oligopoly mark- up	With Oligopoly Mark-Up
<b>Median Discount Fare (One Way in \$)</b>			
Canadian	680	494	523
Japan Air Lines	680	549	575
<b>Average Weekly Frequency</b>			
Canadian	8	8	7
Japan Air Lines	7	8	7
<b>Demand (Thousands of One Way Passengers)</b>			
Canadian	100.0	131.9	120.2
Japan Air Lines	88.1	131.9	123.3
Total Demand	187.8	263.8	243.4
<b>Profits (Millions of \$)</b>			
Canadian	23.9	23.3	26.3
Japan Air Lines	2.0	8.5	14.9
Total Profit	25.9	31.8	41.1
<b>Welfare Impacts</b>			
Consumer Benefits - Aggregate (\$M)		32.7	13.0
Consumer Benefits - Canada (\$M)		9.8	3.9
Consumer Benefits - Others (\$M)		22.9	9.1
<b>Producer Benefits</b>			
Chg. in Canadian Profits		-0.6	2.4
Chg. in JAL Profits		6.6	12.9
Change in Total Profits (\$M)		5.9	15.2
Aggregate Welfare Gain (\$M)		38.6	28.3
Aggregate Welfare Gain to Canada (\$M)		9.2	6.3
Aggregate Welfare Gain to Others (\$M)		28.8	22.0

**Table 8: Price and Frequency Competition with Third Country Routings**

**(Vancouver – Tokyo)**

	Base Case	without Diversion	with Diversion
<b>Median Discount Fare (One Way in \$)</b>			
Canadian	680	494	500
Japan Air Lines	680	549	554
Northwest via Seattle	550	NC*	NC*
United via San Francisco	550	NC*	NC*
<b>Average Weekly Frequency</b>			
Canadian	8	8	8
Japan Air Lines	7	8	8
Northwest via Seattle	7	NC*	NC*
United via San Francisco	7	NC*	NC*
<b>Demand (Thousands of One Way Passengers)</b>			
Canadian	100.0	131.9	133.8
Japan Air Lines	88.1	131.9	134.5
Northwest via Seattle	11.3	NC*	9.0
United via San Francisco	7.5	NC*	5.5
Total Demand	206.6	263.8	282.8
<b>Profits (Millions of \$)</b>			
Canadian	23.9	23.3	24.9
Japan Air Lines	2.0	8.5	11.2
Total Profit	25.9	31.8	36.1
<b>Welfare Impacts</b>			
Consumer Benefits - Aggregate (\$M)		32.7	33.5
Consumer Benefits - Canada (\$M)		9.8	10.1
Consumer Benefits - Others (\$M)		22.9	23.5
<b>Producer Benefits</b>			
Chg. in Canadian Profits		-0.6	1.0
Chg. in JAL Profits		6.6	9.2
Change in Total Profits (\$M)		5.9	10.3
Aggregate Welfare Gain (\$M)		38.6	43.8
Aggregate Welfare Gain to Canada (\$M)		9.2	11.1
Aggregate Welfare Gain to Others (\$M)		28.8	32.7

\* no change

## **HUBBING AND HUB-BYPASSING**

### **Network Developments in a Deregulated European Airport System**

**Jaap de Wit/Peter Uittenbogaart/Thalia Wei-Yun**  
**Civil Aviation Department of the Netherlands**  
**-Aviation Economics Section-**

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## Hubbing and hub-bypassing

### *Introduction*

Most European national airlines were operating radial networks already decades before the U.S. domestic airline market was deregulated and hubbing became the major trend in this market. However, this radial network structure in Europe resulted from international market regulation, i.e. third and fourth freedom routes between the national home base and points abroad. Since at that time most European airlines hardly provided any connectivity between these third and fourth freedom routes, most national airports in Europe hardly functioned as hubs<sup>1</sup> during the pre liberalisation stage.

An exception can be made for a few carriers, like for example KLM, Swissair and SAS, which only had small domestic markets. These carriers needed additional European feed from outside their own domestic market for their long-haul wide-body operations. Therefore in addition to their domestic O&D market airlines generated a transfer market through a scheduled connectivity between long-haul intercontinental and short-haul European/domestic flights. However the relatively limited number of ICA destinations hardly generated any network multiplier effect. The so-called gateway system usually focused on only two banks: for ICA arrivals and ICA departures, respectively.

During the stepwise liberalisation of the EU air transport market various European airlines also started a hubbing system at their national home base next to this gateway function. At several national airports the connectivity between European arrivals and departures substantially improved through an increasing number of daily connection banks which can serve more destinations at higher frequencies. Short-haul to short-haul hubbing apparently took off inside Europe after the liberalisation of route and market entry. Compared to the U.S. domestic market the scale of hubbing has remained limited until now. The limited average travel distance inside Europe and the higher density of public transport and road networks mainly explain this difference.

It can be expected that an increasing number of European hubs will get involved in the next stage of network developments, i.e. multiple Euro hubbing through alliances between European carriers, like Lufthansa and SAS, Swissair and Sabena, BA and Iberia, KLM and Alitalia.

As a result of these hubbing developments and the extra transfer demand generated by it, congestion has exacerbated at most major airports in Europe. This growing congestion and the related noise problems at hub airports evokes a new discussion about the utility of providing substantial airport and noise capacity to foreign transfer passengers, thereby depositing the external noise effects of their travelling on the neighbouring area around the airport. Especially in the Netherlands hubbing is increasingly questioned nowadays by public interest groups in the context of long-term airport planning. Environmentalists increasingly characterise hub&spoke systems as inefficient systems by referring to the superfluous diversion within these networks compared to point to point connections. This seems to be a sufficient argument to announce the end of the hubbing era. The new era would bring a plethora of hub-bypassing routes between smaller uncongested airports that replace the indirect routes through the hub. Although the consequences of a decentralised point to point system in Europe seems to be rather unfavourable to the environment, this prophecy seems also to be rather unlikely from a

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<sup>1</sup> A hub is defined as an airport where the dominant and usually home-based carrier schedules it departing and arriving flights in short consecutive periods (banks or waves), and a transfer system provides an acceptable connectivity between arriving and departing flights.

network-operational point of view. Theoretical arguments against this prophecy are clear and can be based on generalised costs of diversion time, extra transfer time, reduced waiting time and lower fares, compared to the alternative of a direct route, if available anyway. (See also Tretheway and Oum, 1992). However the discussion is also a little complicated by the fact that hubbing and hub-bypassing are two simultaneous network characteristics, which can be explained by the same arguments. Geographical characteristics (route length) as well as the actual route densities and cost competitiveness<sup>2</sup> determine whether new entrants are able to provide a direct connection between two spoke points. All in all however, the general arguments point in the direction that the future picture of network developments in Europe will be increasingly dominated by hub and spoke systems.

As a contribution to the debate on hubbing versus hub-bypassing we have analysed actual network developments between categories of airports in Europe during the last two decades. In this analysis we used the unique collection of ABC/OAG-data for the years 1984, 1990, 1993 and 1997, available in the database of the Dutch Civil Aviation Department. This paper contains the findings of our analysis.

### ***Hypotheses regarding network developments within the European airport system***

First of all we describe a classification of airport categories and route types. This classification provides the basic data for determining whether the hub&spoke phenomenon or the hub-bypassing phenomenon was the dominating trend in the period from 1984 until 1997. More explicitly, the following hypotheses with respect to the hub-bypassing and the hub&spoke phenomenon respectively, were examined.

If the hub-bypassing phenomenon had been the dominating trend, then:

- the percentage of connections between European regional airports would have increased; and/or
- the percentage of frequencies offered between European regional airports would have increased; and/or
- the percentage of seats offered between European regional airports would have increased.

In reverse, if the hub&spoke phenomenon had been the dominating trend, then:

- the percentage of connections between European regional airports and the hub airports would have increased; and/or;
- the percentage of frequencies offered between European regional airports and the hub airports should have increased; and/or
- the percentage of seats offered between European regional airports and the hub airports would have increased.

### ***Classification of European Airports***

All in all, five different airport size categories have been defined a little arbitrarily. Each category allows a minimum and maximum numbers of available seats offered on both intra- and intercontinental routes to and from the airport involved. The classes were calibrated on the data for the reference year 1990. For the other years, viz. 1984, 1993 and 1997, the various classes were scaled according to the average market growth. As a result, Table1 provides an overview of the comparable airport size classes for each of the four years. Data used in the classification were derived from the OAG/ABC timetables for a representative week in July.

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<sup>2</sup> Price discrimination through revenue management is an important tool for the incumbent carrier to counter this new competition.

To transpose these weekly figures into comparable yearly figures, the rule of thumb was used that an annual total is roughly 48 times the representative week in July.

Table 1: Classification of European airports according to seat capacity offered on scheduled passenger flights

Category		cap/week 1984	cap/year 1984	cap/week 1990	cap/year 1990	cap/week 1993	cap/year 1993	cap/week 1997	cap/year 1997
Very Large	>=	175.000	8,4 mill	250.000	12,0 mill	281.250	13,5 mill	350.000	16,8 mill
Large	>=	70.000	3,4 mill	100.000	4,8 mill	112.500	5,4 mill	140.000	6,7 mill
Medium	>=	7.000	340 thd	10.000	480 thd	11.250	540 thd	14.000	670 thd
Small	>=	1.750	84 thd	2.500	120 thd	2.813	135 thd	3.500	170 thd
Very Small	<	1.750	84 thd	2.500	120 thd	2.813	135 thd	3.500	170 thd

Table 2 shows the number of European airports assigned to each of the five categories in each of the four years. The conclusion seems to be justified that the number of European airports in the various categories has remained rather stable during the period analysed. However, the exceptional case is the number of European airports in the category "Very small". Between 1984 and 1990, this number increased by more than a 100, a relative growth of about one third. This significant increase is probably correlated with the gradual liberalisation of European aviation. Cross-border interregional aviation within the EU had already been liberalised in 1983. From this moment on, regional airlines were free to start interregional services between secondary and/or tertiary airports with a maximum aircraft size of 70 seats. As a consequence an increasing number of smaller general aviation airports were served by cross-border scheduled passenger services. From 1987 on, all aviation in the EU has gradually been liberalised in three consecutive steps. In 1997 the liberalisation of the EU air transport market was completed when cabotage was fully allowed.

Table 2: Number of European airports according to seat- capacity class for scheduled passenger services

Category		1984	%	1990	%	1993	%	1997	%
Very Large	>=	5	0,9 %	4	0,6 %	5	0,7 %	5	0,8 %
Large	>=	12	2,2 %	15	2,3 %	13	1,9 %	15	2,3 %
Medium	>=	97	17,5 %	95	14,4 %	96	14,3 %	99	15,0 %
Small	>=	151	27,3 %	140	21,2 %	152	22,7 %	133	20,1 %
Very Small	<	289	52,2 %	405	61,5 %	405	60,4 %	408	61,8 %
Total		554	100 %	659	100 %	671	100 %	660	100 %

Source: OAG/ABC

Based on the aforementioned classification of European airports,

- the number of intra-European scheduled passenger routes,
  - the number of frequencies offered on these intra-European routes, as well as
  - the seat capacity offered on these intra-European routes,
- were selected from the OAG/ABC time schedules for the respective years in the analysis.

### *Classification of route types*

To analyse network developments between the different airport categories, three different route types can be distinguished among European airports:



- interregional connections, i.e. connections offered between or within the airport categories *very small*, *small* and *medium*;
- interhub connections, i.e. connections offered between or within the airport categories *large* and *very large*;
- hub&spoke connections, i.e. connections offered between the airport categories *very small*, *small* and *medium* on the one hand and the airport categories *large* and *very large* on the other.

### ***Historical developments in numbers of connections***

Table 3 shows that the number of interregional routes was slightly below the average market growth rate for the period of 1984-1990 and slightly above the average market growth rate for the period of 1990-1997. All in all, there has not been a significant shift in the distribution of intra-European connections over the route types interregional, interhub and hub&spoke. On average one may conclude that the distribution according to route type has been fairly stable. The development of the number of intra-European connections does not render any convincing evidence for either the hypothesis that there has been an intensification of interregional traffic in Europe or the hypothesis that there has been a strong development towards a hub&spoke network structure in Europe.

Table 3: Number of intra-European scheduled passenger connections according to route type

Category	1984	%	1990	%	1993	%	1997	%
Interhub connections	116	5,7%	154	5,6%	123	4,1%	172	4,8%
Average annual growth %			4,8% 1984-1990		-7,2% 1990-1993		8,7% 1993-1997	
Hub&Spoke connections	790	39,0%	1078	39,4%	1170	39,3%	1403	38,8%
Average annual growth %			5,3% 1984-1990		2,8% 1990-1993		4,6% 1993-1997	
Interregional connections	1117	55,2%	1503	55,0%	1687	56,6%	2039	56,4%
Average annual growth %			5,1% 1984-1990		3,9% 1990-1993		4,9% 1993-1997	
Total	2023	100,0%	2753	100,0%	2980	100,0%	3614	100,0%
Average annual growth %			5,2% 1984-1990		2,9% 1990-1993		4,9% 1993-1997	
							4,1% 1990-1997	

Source: OAG/ABC

### ***Historical developments in frequency levels and seat capacity***

Tables 4 and 5, on the contrary, show a major shift in the distribution of both frequencies and seat capacity offered on interregional, interhub and hub&spoke connections. The share of interregional traffic in overall totals has dropped significantly, both in frequencies and in seat capacity. This highlights the fact that interregional traffic is losing ground especially to hub&spoke traffic. The share of interhub traffic is fairly stable, in terms of frequencies as well as in terms of seat capacity.

We therefore conclude that the findings for the period of 1984 - 1997 show an increased hub-orientation of the regional airports, instead of an increased orientation towards each other. In other words, hubbing has substantially increased in the European market, whereas the contrary is true for hub-bypassing in the EU during the period analysed.

Table 4: Number of weekly intra-European scheduled frequencies<sup>1)</sup> for the various route types

Category	1984	%	1990	%	1993	%	1997	%
Interhub connections	3120	13,4%	4832	14,1%	5044	13,1%	7021	14,5%
Average annual growth %			7,6% 1984-1990		1,4% 1990-1993		8,6% 1993-1997	
Hub&Spoke connections	9923	42,5%	15445	45,1%	18042	46,9%	23833	49,2%
Average annual growth %			7,7% 1984-1990		5,3% 1990-1993		7,2% 1993-1997	
Interregional connections	10285	44,1%	13938	40,7%	15362	40,0%	17630	36,4%
Average annual growth %			5,2% 1984-1990		3,3% 1990-1993		3,5% 1993-1997	
Total	23328	100,0%	34215	100,0%	38448	100,0%	48484	100,0%
Average annual growth %			6,6% 1984-1990		4,0% 1990-1993		6,0% 1993-1997	
							5,1% 1990-1997	

1) Frequency: a return flight, i.e. an outgoing and an incoming aircraft movement

Source: OAG/ABC

Table 5: Total seat capacity<sup>2)</sup> offered on a weekly basis for the various route types in intra-European scheduled passenger traffic

Category	1984	%	1990	%	1993	%	1997	%
Interhub connections	914 thd	20,5%	1430 thd	20,7%	1446 thd	18,5%	1990 thd	20,3%
Average annual growth %			7,7% 1984-1990		0,4% 1990-1993		8,3% 1993-1997	
Hub&Spoke connections	2073 thd	46,4%	3365 thd	48,7%	4071 thd	52,1%	5328 thd	54,4%
Average annual growth %			8,4% 1984-1990		6,6% 1990-1993		7,0% 1993-1997	
Interregional connections	1479 thd	33,1%	2121 thd	30,7%	2291 thd	29,3%	2469 thd	25,2%
Average annual growth %			6,2% 1984-1990		2,6% 1990-1993		1,9% 1993-1997	
Total	4466 thd	100,0%	6916 thd	100,0%	7008 thd	100,0%	9787 thd	100,0%
Average annual growth %			7,6% 1984-1990		4,1% 1990-1993		5,8% 1993-1997	
							5,1% 1990-1997	

2) Seat capacity: Number of seats on both the outgoing and the incoming flights

Source: OAG/ABC

This conclusion is confirmed by the growth in transfer figures at several European airports collected by Kuehne (1999) for the last few years. (See appendix)

### *Two indicators for hub developments in the EU*

The probability of increased hub&spoke connections as indicated by Tables 4 and 5 requires a more detailed analysis on the actual hub developments initiated by a limited number of European national carriers at their respective home bases.

Two important indicators can be used to analyse these hub developments in more detail.

- Increasing numbers of spokes as well as increased frequencies provided on these spokes should be reflected by a higher frequency growth of the home-based carrier when compared to the frequencies of other carriers at the airport involved. Therefore we first pay attention to this plausible increase of the frequency share as an indicator for the growing hub dominance during the period 1984-1997.
- Furthermore an analysis of the daily waves pattern at the hub airport can reveal in more detail the actual type of hubbing. Numbers of waves (or connecting banks) as well as categories of connecting traffic (long haul and/or short haul) have to be taken into account.

### *Hub dominance*

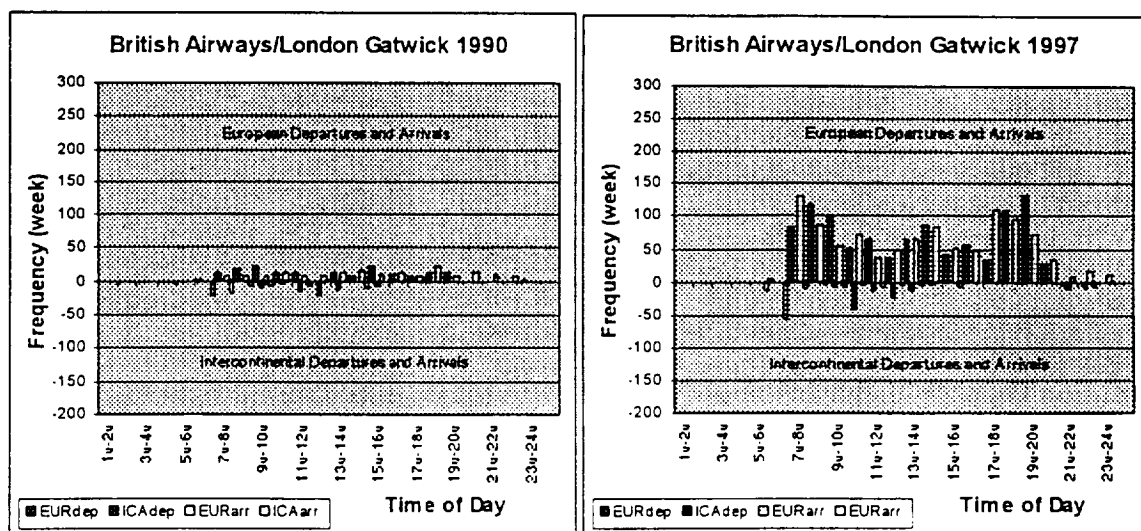
We analysed seventeen European airports mainly in the categories very large and large. (See also Tables 1 and 2).

Table 6: Hub dominance

Airports	Home-based carrier	Hub dominance 1990 (in % total frequencies)	Hub dominance 1997 (in % total frequencies)		category 1990	category 1997
London Heathrow	British Airways	38	39	+1	very large	very large
Paris Charles de Gaulle	Air France	39	41	+2	very large	very large
Frankfurt	Lufthansa	45	56	+11	very large	very large
Rome	Alitalia	43	62	+19	very large	very large
Amsterdam Schiphol	KLM	31	45	+14	large	very large
London Gatwick	British Airways	19	65	+46	large	large
Zurich	Swissair	50	51	+1	large	large
Brussels	Sabena	43	47	+4	large	large
Paris Orly	Air Inter	24	45	+21	large	large
Munich	Lufthansa	50	53	+3	large	large
Madrid	Iberia	59	55	-4	large	large
Barcelona	Iberia	61	51	-10	large	large
Copenhagen	SAS	47	52	+5	large	large
Milan Linate	Alitalia	43	55	+12	large	large
Vienna	Austrian Airlines	41	34	-7	medium	medium
Milan Malpensa	Alitalia	29	25	-4	medium	medium

Frequency shares for dominant carriers at major domestic hubs are usually higher (50-70%) than the U.S. gateways (less than 40%), where a larger share belongs to foreign carriers. Table 6 indicates that most home-based carriers have consolidated their position at their home bases in Europe. Especially British Airways at London Gatwick, Air Inter at Paris Orly and Alitalia at Rome Fiumicino have substantially increased their frequency share.<sup>3</sup> One has to be careful to use these figures as a single indicator for hub developments. The example of British Airways at London Gatwick illustrates the dangers of misinterpretation. A co-ordinated wave structure is missing in 1997 despite an increase of the frequency share by 46 % in the period 1990-1997. (See diagram 1).

Diagram 1: Traffic patterns of British Airways at London Gatwick

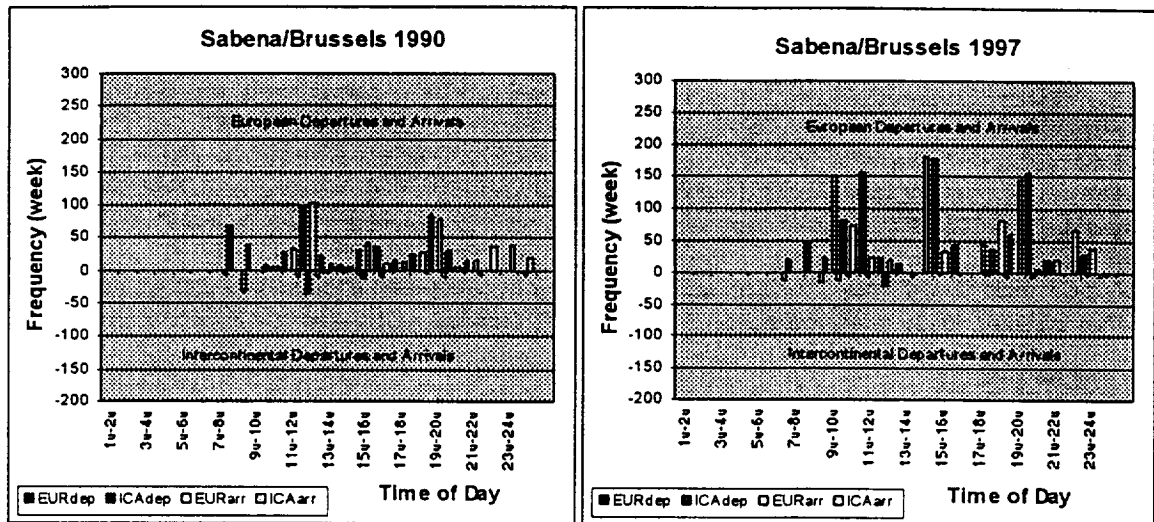


The other way around, notorious hubbing carriers do not always demonstrate a substantial increase in their frequency share. This is mainly a consequence of our selectively focusing on

<sup>3</sup> A HHI value, reflecting the frequency shares of the various airlines, is intentionally not used here, since the separate share of the dominant carrier as such can no longer be recognised.

the national carrier alone, without taking account of the impacts of alliances and stakes in other carriers, which also operate at the home base of the alliance partner. For example, KLM alone shows a frequency share at Amsterdam Airport of 45%. However, if the frequencies of the alliance partners and subsidiaries are also included, the frequency share rises to 69%. Even a stagnant frequency share during the period of 1990-1997 can go hand in hand with a strong restructuring of the traffic pattern towards a hubbing system. Sabena, for example, was able to reorganise the daily frequency pattern as an Euro hubbing system without any substantial change in its frequency share at Brussels as diagram 2 demonstrates.

Diagram 2: Traffic patterns of Sabena at Brussels airport Zaventem



### Wave structures

As indicated by Bootsma (1998) hub systems at an airport can be classified from the operational point of view by the triple (N,H,S), in which N= the number of waves, H= hub repeat cycle, and S = the stabilising system (home based or not, or mixed). From a functional point of view the type of connection waves completes this triple: combined long-haul/short-haul waves or simple short-haul waves.

The daily frequency patterns of the airports analysed indicate that in 1997 six out of seventeen airports demonstrated co-ordinated wave structures according to table 7. It is plausible that in the near future also Malpensa will rapidly change its position within table 7: the hub dominance of Alitalia strongly increases in 1999 after the opening of the renovated airport and Alitalia is now developing a wave system at this airport.

The impact of liberalisation can be derived from the differences between Table 7 and Table 8. Before the liberalisation the hubbing phenomenon was non existent. Since the liberalisation however, hubbing has become a prerequisite for airlines to enable the new network competition.

Table 7: Wave structures 1997

1997		Wave structures		
		Present	limited	absent
	high	Munich (4) Frankfurt (4)	Zurich Copenhagen	London Gatwick Madrid Barcelona Rome Fiumicino Milan Linate
Hub dominance <sup>4</sup>	medium	Brussels (3) Paris Charles de Gaulle (5) Amsterdam (3,5)	Vienna	London Heathrow Paris Orly
	low			Milan Malpensa

Table 8: Wave structures 1990

1990		Wave structures		
		Present	limited	absent
	high		Zurich	Munich Madrid Barcelona
Hub dominance	medium	Frankfurt	Copenhagen Vienna	London Heathrow Brussels Paris Charles de Gaulle Milan Linate Rome Fiumicino
	low		Amsterdam	London Gatwick Paris Orly Milan Malpensa

In 1990, only Frankfurt airport demonstrated a clear daily peak pattern. Five other airports also showed a rudimentary wave structure. From this column only Amsterdam airport has been able to move to a fully-fledged hub airport. Paris Charles de Gaulle however, shows the largest change within a very short throughput time: from a non-hubbing airport to a complete hub&spoke system.

All in all it can be concluded that hubbing is a clear phenomenon in Europe nowadays, be it at a slowly increasing number of airports: Munich, Paris Charles de Gaulle, Frankfurt Brussels and Amsterdam, and Copenhagen, Vienna and Zurich in the second range.

In the context of airline alliances it can be expected that more airports will develop a clear hubbing pattern in the near future. The geographical concentration of the currently operating hubs indicates a rapidly intensifying competition between the airline networks rooted at these hubs.

### Hub categories

From a functional point of view hubbing can be further categorised by looking at the mixture of long-haul and short-haul operations. Following this approach, five hub types are relevant:

- the *ICA gateway hub* which connects short haul Euro destinations/origins and long haul ICA origins/destinations as well as a limited number of ICA-ICA transfers;
- the *Euro hub* which focuses on the connectivity between European origins and destinations;
- the *Combi hub* which integrates the ICA gateway function and the Euro hub function;
- the *Random hub* which provides a high random connectivity due to the large volume of arriving and departing flights so that waiting time intervals remain within acceptable limits

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<sup>4</sup> Hub dominance of a home-based carrier is strong if the frequency share is larger than 50% and low if the frequency share is smaller than 30%.

- in the perception of the consumer; and
- the *Non hub*, which does not provide any useful connectivity to the transfer passenger.

Table 9 contains the classification of a number of major European airports according to these five concepts.

Table 9: hub-airport types

Hub-airport	hub category 1990	hub category 1997
Frankfurt	Combi-hub	Combi-hub
Munich	Non-hub	Eurohub
Paris Charles de Gaulle	Non-hub	Combi-hub
Brussels	Non-hub	Eurohub
Amsterdam	Gateway	Combi-hub
Vienna	Non-Hub	Euro-hub
London Heathrow	Random hub	Random hub
London Gatwick	Non-hub	Non-hub
Rome Fiumicino	Non-hub	Non-hub
Zurich	Gateway	Gateway

### *Concluding remarks*

The foregoing analysis indicates that the liberalisation of the EU airline industry went hand in hand with an ongoing transformation of national EU airports into different hub types.

The assumption that congestion at the major European airports would be a sufficient reason to counter this development into a point to point network system is not sustained by the figures derived from the ABC/OAG database, available at the Dutch Civil Aviation Department.

On the contrary, the process towards a more sophisticated hubbing system in Europe is well under way. Not only more airports are getting involved in this process, also a hierarchy of hub airports within alliances may be plausible as a next step in this hubbing process. However, the volatility of cross border airline alliances dictates the relative (in)stability of these hub airport systems during the next few years. Whether the currently emerging multiple hub relationship will hold, is an unanswered question. For example, this question relates to Copenhagen and Frankfurt in the Star alliance, Milan Malpensa and Amsterdam in the Wings alliance, Zurich and Brussels in the Qualiflyer alliance and London Heathrow and Madrid in the One World alliance.

Changes in airline alliances can have tremendous impacts on airport planning in the EU during the next decade. If for example Air France is incorporated in the Wings alliance through its close connections with Continental (the carrier partly owned by KLM's partner NorthWest), Paris Charles de Gaulle might become the primary European hub in an AF-AZ-KLM system.

The near future probably clarifies whether the number of primary hubs in Europe will be limited to London, Paris and Frankfurt and followed by a number of secondary hubs like Munich, Copenhagen and Brussels. The alternative would be a more decentralised multiple hub system will emerge due to increasing congestion problems at these primary hubs.

Finally, with regard to the European airport system we can conclude that the crucial question is not "hubbing versus hub-bypassing" but "single layer hubbing versus multi layer hubbing". Airline co-operation and alliances will ultimately determine the answer on this question.

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# **Environmental sustainability, airport capacity and European air transport liberalization: irreconcilable goals?**

Brian Graham

*School of Environmental Studies, University of Ulster, Coleraine, Northern Ireland BT52 1SA, UK*

## **Introduction**

The general aim of this paper is to discuss the principal tensions that exist between policies for air transport liberalization in the European Union (EU) and those directed at environmental sustainability, conflicts which come together in the nexus of airport capacity. While concentrating on one particular transport mode, the discussion is more widely informed by the mounting recognition that present and projected trends in mobility in Europe cannot be sustained and that, more generally, 'the belief in the desirability of perpetual growth in mobility and transport has started to fade' (Greene and Wegener, 1997, p. 177). As Black (1998, p. ) argues, 'history would suggest that it is not the transport vehicle....[but its]....excessive use....that creates the problem'.

At least four interested parties or stakeholders can be identified in the relationships between environmental sustainability, airport capacity and European air transport liberalization. The airlines themselves, transformed by liberalization into a resolutely free-market industry, can often express unreconstructed attitudes to environmental issues, which are perceived to interfere in their primary goal of making money. Secondly, environmental objections originate in the concerns of wider society, although these may range from empirically verifiable complaints about air transport noise and atmospheric pollution to the actions of an idealistic lobby prepared to sacrifice economic growth to its perceptions of environmental needs. Demands for environmental quality increase with standard of living (Maddison, 1996), and it is the experience of airport operators that the maximum number of complaints regarding aviation originate from high-income residents in their immediate hinterlands. Ironically, the demand for air transport also increases with income and those members of society complaining most vociferously may also be those flying most frequently. As airline customers, they want maximum mobility, combined with cost or status advantages. Thirdly, if it is accepted that unconstrained mobility is no longer a feasible goal for society, then regulators are required to somehow ration demand for airport capacity and reduce the environmental externalities of air transport. Finally, the airport operators occupy the interface between this conflicting mesh of interests.

The essential assumption that underpins the paper's argument is that - at an aggregate level - the EU lacks sufficient airport capacity - however defined - to accommodate projected growth trends in air transport, and that the provision of extensive additional infrastructure is extremely unlikely because of environmental constraints. More specifically, the paper has three objectives. Initially, we address the concept of environmental sustainability and its relationship to capacity issues in EU air transport. Secondly, the problems of European airport capacity are assessed, as is the potential for modal shift. Finally, the bulk of the discussion is given over to the ways in which the often incompatible interests and goals of the various stakeholders outlined above define complex tensions that immensely complicate any resolution of the relationships between environmental sustainability, airport capacity and liberalization.

## **The concept of environmental sustainability and its relationship to capacity issues in European air transport**

Transport in general constitutes the most important negative environmental externality of the Single European Market (SEM), creating noise, atmospheric pollution and consuming large areas of land, while being dependent on non-renewable energy



resources. Although its aggregate impact is minor compared to road traffic, air transport accounts around 10% of all transport energy consumption in the EU and is responsible for approximately 15% of all CO<sub>2</sub> emissions (Stanners and Bourdeau, 1995). However, the technological returns on reducing air transport's negative environmental externalities are diminishing so the sector's very growth seems likely to ensure that this impact will increase in the future. In addressing the relationships between air transport infrastructural provision and the environment, two key terms - sustainability and capacity - require definition.

### *Sustainability*

The meaning of sustainability to transport has occasioned widespread discussions in recent years, not least because it is a qualitative rather than operational term (see, for example, Pearce, 1993; Black, 1996; Nijkamp and van Geenhuizen, 1997). The common thread in these debates is provided by the dual invocation of sustainability put forward in the 1992 Rio Declaration, which attempted to reconcile the needs, especially those of the world's poor, with protecting the environment's capacity to meet present and future needs. Thus Black (1996, p. 151) defines sustainable transport as 'satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs'. According to the Aviation Environment Federation (1997), sustainability describes integrated transport systems and infrastructure, which enable the socio-economic needs for movement of goods and people to be met within the long-term carrying capacity of the planet's ecological systems. Greene and Wegener (1997) argue that sustainability as applied to transport has three basic conditions: that the rates of use of renewable resources do not exceed their rates of generation; the rates of use of non-renewable resources do not exceed the rate at which sustainable renewable substitutes are developed; the rates of pollution emission do not exceed the assimilative capacity of the environment. Air transport fails outright to satisfy the first two conditions and probably also the third. In the longer term (perhaps 2050+), global air transport is not sustainable on any basis because there is, as yet, no feasible substitute fuel for oil, hydrogen-based fuels being the only apparent possibility.

It must be emphasized that in addition to concerns with environmental carrying capacity, sustainability also invokes connotations of social needs and equity. The problem is that tactics aimed at achieving social equity also encourage mobility. 'Modern transport affords mobility, facilitates post-Fordist production and allows political cohesion. Degrees of access to transport networks affect social patterns at all levels of spatial aggregation' (Button and Nijkamp, 1997, p. 215). The equity implications of mobility creation are central to the social economy model that underpins the ideological construction of the EU and its concern that geographical location should not be the primary determinant of the life chances of the Union's 370 million population. The European Commission in general tends to refer to 'sustainable mobility', which is unfortunate as there are strong grounds for believing that mobility as currently practiced in developed countries is itself unsustainable (Fergusson *et al.*, 1994); infinite mobility is not infinitely desirable (Bleijenberg, 1995). It is access, not mobility *per se*, which is the critical issue in social needs and the enhancement of accessibility is a key process in Commission policies aimed at alleviating regional disparities in wealth in the EU. An efficient transport system is also vital to the integration and efficient functioning of the SEM. Inevitably, however, the provision of transport infrastructure aimed at these goal also encourages mobility. In sustainability terms, therefore, the EU requires a transport strategy, which reconciles a curb on mobility with competing demands for accessibility related to: the need for competitive efficiency; the EU commitment to geographical accessibility and social equity for all its citizens; and environmentally sustainable development (Button and Nijkamp, 1997).

A major difficulty in achieving any such resolution, however, is that the responsibility for policy-making within the EU is divided between the various Directorates-General of the Commission, no less than four - DGs IV, VII, XI and XVI (dealing respectively with competition, transport, environment and regional development) - being directly involved in issues related to air transport and the

environment. Already at odds over the regulation of competition within EU air transport, DGs IV and VII are concerned primarily with the market efficiency of the industry and the implementation of the Single Aviation Market, effectively created by the Three Packages of airline liberalization measures, introduced progressively between 1988 and 1997. This policy initiative, which originated from DGVII, is concerned directly with promoting competition in air transport and removing barriers to market entry. However, as is a characteristic of all transport modes, such policies do not encourage individual restraint on the part of any one airline, because such actions would not be 'compatible with rational self-interest, not least while any other [company] reserves the right to use the resource [airport capacity] as much as they choose' (Maddison, 1996, p. 10). DGIV clearly regards airport capacity as more than a straightforward resource. It seems intent, for example, on using regulation of runway slots - the most obvious and contentious manifestation of capacity - to promote intra-EU market entry, particularly by low-cost airlines. The slot is a strategic weapon in a competitive market-place, the major European airlines having a vested interest in ensuring shortages at their principal hubs (so long as they themselves have sufficient) in order to deter market entry and control competition. The Association of European Airlines (AEA) estimates that a runway is at saturation point if 70% of its slots are being used; peak-time slots would have been used fully long before that. In attempting to regulate the anti-competitive connotations of the consolidation of EU airlines into internal alliances and more extensive global coalitions, DGIV opposes the concept of airline ownership of - and trade in - slots and is demanding that British Airways (BA) and Lufthansa surrender significant numbers at Heathrow and Frankfurt, respectively, in return for regulatory approval of their separate global alliances.

More widely, DGVII is responsible for the Common Transport Policy and its principal *modus operandi*, the multi-modal Trans-European Transport Network (TETN). Its role is to enhance accessibility and integration, while harmonizing national networks into a macro-network for the EU as a whole, not least by providing missing connections (often at border locations) and the attempted elimination of bottlenecks (CEC, 1994; Banister *et al.*, 1995). While the TETN focuses on High Speed Trains (HSTs) rather than air transport for inter-city public transport within the EU, its commitment to competitive efficiency also includes inter-modal complementarity. Thus an essential element of the network lies in the development of the most important EU airports as multi-modal high-speed interchanges.

The TETN is also linked to other EU policies and objectives being articulated by DGXVI through the Regional Development and Structural Funds, and aimed at operationalizing the commitments to social solidarity, cohesion and convergence that lie at the heart of European integration. In particular, this requires investment in transport links to rural and peripheral areas, the assumption being that long-term cohesion-oriented policies demand a coherent and efficient transport system guaranteeing continuity of service (CEC, 1996a). In DGXVI's terms, the notion of 'sustainable mobility' (not only in the sense of emissions and noise but also of the social equity connotations that underpin the integrated spatial planning ethos of the TETN) has become the 'central goal of transport policy' (CEC, 1996a, p.76). In reality, however, convergence and cohesion policy may simply ensure the construction of transport infrastructure that otherwise would not have been built, under-utilization of expensive resources providing another dimension to the airport capacity debate.

It is required of EU transport and cohesion policies that they be environmentally sustainable, but it can be argued that both enhance the demand for mobility (without necessarily improving accessibility), whereas environmental policy - the remit of DGXI - tends to assume that present and projected demand for mobility is unsustainable and must therefore be reduced. In the EU's Fifth Environmental Action Programme, endorsed in 1993 and subtitled 'Towards Sustainability', transport is identified as one of five target sectors in recognition of the point that it can never be environmentally neutral. The Programme argues that present trends in air (and road) transport are leading towards greater environmental costs - congestion, pollution, wastage of time and value, damage to health, and danger to life (CEC, 1996b).

The most recent assessment of the Programme, and Agenda 21, the general and politically compromised strategy for sustainable development set up after the 1992 Earth Summit (and reaffirmed at Kyoto in 1998), concludes that the transport sector is displaying an increased awareness of the unsustainability of present trends (CEC, 1997a). Traffic growth, however, is eroding attempts to move towards a sustainable system, air transport having a higher growth rate than any other transport mode. One stark conclusion is apparent; transport policy must be designed to reduce demand for mobility, a demand which is derived and can therefore be altered. But as Greene and Wegener warn (1997, p. 180), transport demand policies to mitigate the environmental impacts of transport 'are frequently dwarfed by countervailing market developments'. Nowhere is this more apparent than in the EU's air transport industry.

*Airport capacity and its environmental context*

Airport capacity takes several forms. It includes: airspace and the role of Air Traffic Control (ATC) techniques in the maximization of air transport movements (ATMs); airport infrastructure - runways, aprons, piers, and terminals; and terminals for terrestrial transport as airports (particularly the most important) are multi-modal interchanges. Above all, however, it is essentially the case in the EU that airport capacity *is* - or is soon to become - environmental capacity, with environmental criteria, rather than those related directly to physical infrastructure capacity increasingly determining the magnitude of ATMs. Airports are increasingly left free to plan operations, provided that the sum total of the environmental impacts of their activities do not exceed a pre-determined level.

Environmental capacity invokes a wide range of concerns, which include: noise from aircraft and surface transport; atmospheric emissions from aircraft engines; surface access congestion at airports; land-use severance effects of airports and their impact on visual amenity; effluents; and waste management. Noise in particular remains critical to environmental capacity because it is the principal source of complaints and the most likely cause of political involvement in restricting the use of existing - and further development of - infrastructure. Commercial jet transports, currently in operation, are divided into Stage II and III types, classifications that relate to Chapters 2 and 3 of Annexe 16 to the Chicago Convention. All new aircraft must meet Chapter 3 requirements, although these were laid down as long ago as 1976. In 1990, the International Civil Aviation Organization (ICAO) agreed to phase out all Chapter 2 aircraft. If these are to remain in service beyond 2002, the EU target date for final Chapter 3 compliance, they will either have to be hush-kitted to those standards, or re-engined.

The enforcement of these requirements will not, however, remove the problem of aircraft noise. New aircraft are quiet, only when compared to their predecessors. Although the spatial extent of noise footprints around airports has been reduced, the problem of aural pollution will remain. The high-bypass turbo-fan engines used in modern aircraft are probably already as quiet as is technically feasible although the possibility exists that, assuming the necessary investment in research, further gains might accrue from the development of prop-fans. More immediate reductions will most likely accrue from reductions in airframe noise, which may account for around 50% of total aircraft noise on airport approaches. Serious concerns exist, however, that increased ATMs are compromising noise reductions, while larger aircraft create more noise, even if they do comply with Chapter 3 limits. In these contexts, any enhancements to airport capacity - whatever their form - depend on a proactive environmental policy on the part of airport operators, addressing not only noise but the entire suite of environmental externalities engendered by the air transport industry. Although expenditure on environmental issues may not be justified in terms of direct economic costs and benefits, any future enhancement of capacity is predicated on a visible and effective environmental policy.

## The problem of European airport capacity

### *The airport capacity problem*

European airports have long been perceived as having capacity problems although these have been offset by innovations in air traffic management and control. In reality, the picture is rendered more complex by three important factors, which, in turn, create a geography of airport capacity restrictions. These are: variations in the form of airport infrastructure itself; the growth in demand for air transport; and the distribution of that demand for air transport.

First, as *Table 1* shows, runway capacity is a function of an airport's layout, parallel runways unsurprisingly supporting larger capacities than converging or single runways. The data also indicate that irrespective of geometry, only marginal increases in runway capacity can now be achieved without the construction of additional infrastructure. There remains some potential in EU harmonization of ATC, and in innovations such as 'mixed mode' runway operations in which the same runway is used for landings and take-offs.

Secondly, aggregate demand for air transport remains driven by GDP growth, although changes in industrial organization (especially just-in-time delivery) and lifestyle (particularly enhanced consumption of holidays, a market driven by increased real incomes) also contribute significantly. In addition, European air transport liberalization has helped grow the air transport market through price competition (Graham, 1997a; CEC, 1997b), as have the strategic actions of the major airlines in this reformed market-place - a point to which we return later. Growth rates for air transport in Europe have been rising consistently since the global slump in air travel induced by the Gulf War in 1991. In 1997, for example, AEA airlines carried 164.4m passengers on international routes, a 10.7% increase over 1996 (AEA, 1998). Future projections vary but the 'predict and provide' scenarios of the aircraft manufacturers offer some (rare) agreement. *Airbus Industrie* estimates an average annual growth rate in traffic of 5.3% up to 2001, and a more conservative 4.6% between 2002-2011. Boeing (1998) is predicting an average 5% growth in air travel over the next ten years. Because such growth is exponential, these annual increments are equivalent to a doubling in demand every 12 years. *Airbus* estimates that the global population of passenger aircraft will double from 9,700 in 1998 to 17,900 in 2018, flights increasing by 88% over the same period. The number of runway movements is expected to increase at rather lesser rates (*Table 2*), an imbalance which implies that at least some traffic growth is - and will be - accommodated by larger aircraft. One major imponderable in such predictions is the future impact of information technology on the demand for air travel.

Thirdly, both the demand for air transport in the EU and congestion are spatially concentrated. Demand is heavily biased towards Europe's most dynamic and urbanized vital axis, stretching from Manchester in the north-west and Helsinki in the north-east to Rome, Barcelona and Madrid in the south. This axis contains virtually all the EU regions with above-average GDP/capita and the most important airport hub systems (Graham, 1998). Airport capacity problems - and the congestion and pollution created by terrestrial transport modes - are also concentrated in this central vital axis, although a secondary nucleus comprises certain of the leisure-oriented airports of southern Europe. In essence, Europe is running out of airport capacity - however defined - in the regions in which demand for air travel is most heavily concentrated. Although more than 450 European airports receive scheduled service, the 20 busiest - largely concentrated in the EU's dominant axis - account for about 55% of all scheduled seats and virtually all long-haul traffic (*Figure 1*) (Boeing, 1998). While capacities have increased markedly at some of these airports, a now slightly dated survey of the 29 European airports handling more than 5 million passengers per annum in 1994, estimated that by 2005, 25 will have runway, and 26 terminal, capacity shortages respectively (AEA, 1996). All will be congested by 2010. While the maximum hourly movements at most major airports will increase by 2015, the extra capacity is insufficient to meet projected growth in almost every instance (*Table 2*). Conversely, a substantial number of airports capable of handling more than immediately local or regional traffic have adequate capacity for the foreseeable future (*Figure 2*), and while many of these serve either secondary cities or the more peripheral regions of the present

and future EU, some are actually located within the vital axis, thereby providing some limited potential for traffic diversion.

### *Coping with growth*

In comparison with the projected growth rates for air transport, the plans for constructing new airport infrastructure in the EU are modest. Munich Franz Josef Strauss - the last major greenfield airport to be built in Europe - and the reconstructed facilities at Milan Malpensa and Oslo Gardermoen, both completed in late 1998, largely replaced existing capacity, although obviously they also added some. The same is true of those airports currently in the planning stage - Berlin, Lisbon and Athens Spata. Terminal capacity is being increased at a number of airports although many of these are not capacity restricted anyway. While it is easier to get permission for terminals than runways, by late 1998 the planning inquiry into Heathrow's proposed Terminal 5 (T5) had sat longer than any other inquiry in UK planning history; even if approved, the terminal will not be fully operational until 2015-16. The construction of runways, or even their lengthening, creates even more strenuous opposition. Consequently, one recent survey listed 47 existing European airports at which terminal expansion is projected or in progress, but could identify only 12 instances of new runways being planned (Simon, 1998).

Thus it appears that an irreconcilable tensions exists between projected growth figures for air transport in Europe and the provision of the infrastructure necessary to cope with that growth. To put it more simply, the projected growth rates cannot be sustained within current or projected air transport infrastructure capacity. It also seems fair to assume that the lack of political will to build additional capacity - either at the EU or Member State scale - owes much to the environmental opposition that such plans encounter. Consequently, policy initiatives to cope with the growth in air transport - most notably the TETN - have been directed as much at modal shift as at building new airport infrastructure. Some short-haul air traffic could be diverted to HSTs, which consume much less energy per passenger km, allowing airlines to concentrate on their unchallenged hegemony in intercontinental travel. For point-to-point business traffic, HSTs can compete effectively with air transport on inter-city journeys of less than three hours (approximately 500 km); the threshold extends to 1,000 km for leisure traffic. One leading EU regional airline, the German carrier, Eurowings, has admitted that regional air services are no longer worth flying if the journey time by rail is less than three hours (*Flight International*, 1997).

The potential for HST modal shift was first demonstrated by France's *TGV*, which reportedly captured as much as 90% of the Paris-Lyon market. Elsewhere, the *AVE* service has over 80% of the Madrid-Seville market, compared to the 33% share held by conventional rail in 1991 (CAA, 1998). In Germany, Lufthansa, which already uses Inter-City Express (*ICE*) trains, wants to shut down domestic air services from Frankfurt to Cologne, Düsseldorf and Stuttgart, but is facing difficulties in guaranteeing passengers the equivalent level of service). Although early HST development concentrated on city centre-city centre linkages, the most recent network additions exploit the added value offered by this mode when it interfaces with other high-speed systems (Thompson, 1995). The construction of *TGV* stations at Paris Charles de Gaulle and Lyon Satolas originated the process now being pursued through the TETN, in which the integration of road, conventional rail, HST and air transport modes at major airports will produce a succession of sophisticated mainports across Europe, allowing the seamless integration of intra-urban, regional, national, international and global traffic flows (Graham, 1995). These will include Brussels National, Amsterdam Schiphol, Düsseldorf Rhein-Ruhr, Munich Franz Josef Strauss, Frankfurt International and Milan Malpensa, although the TETN will not be completed until after 2010.

Despite the potential for modal shift and the increasing integration of airline and HST operations (and even ownership) in the EU, this is not in itself a comprehensive solution to the problem of air transport capacity, partly because of the segmented nature of the air transport market. Scheduled passenger services - which place the greatest demand on airport capacity - account for only half the passenger market. The potential

for HST modal shift is largely restricted to the EU's dominant axis where the dense, juxtaposed city-pair markets necessary to support investment are concentrated. The strategy is also irrelevant to the Inclusive Tour (IT) industry, which accounts for the other half of the passenger market. Arguably, however, this sector is - inadvertently - more compliant with sustainability requirements, its economics strongly encouraging the employment of the most modern fuel-efficient aircraft types at very high load factors, and often utilizing off-peak times or under-utilized (or capacity-rich) regional airports. The freight market is distinctly problematical, however, given its dependence on night flights and older aircraft (even if hush-kitted); also, much intra-European 'air freight' is actually trucked, thereby adding to road congestion and pollution. In sum, therefore, modal shift offers some contribution towards alleviating problems of airport capacity but it is not remotely a comprehensive solution.

### **The stakeholders in the environmental sustainability- airport capacity relationship**

#### *The regulators*

The incompatibility of growth trends and projected infrastructure availability, combined with the limited potential for modal shift, suggests that any resolution of the tension, which exists between projected demand for air transport and airport capacity, lies in regulatory measures to curb that growth altogether. It has long been accepted that airport operations can be restricted for environmental reasons, night curfews or quotas, and bans or restrictions on Chapter 2 aircraft being obvious examples. Again, political factors can influence capacity limits, one notable example being the legally-binding agreement preventing the construction or opening of a second runway at London Gatwick (the busiest single-runway airport in Europe) before 2019. The slot-capacity of the existing infrastructure at Düsseldorf Rhein-Ruhr, for example, is constrained for environmental reasons, while the Dutch government's attempt - albeit now revised - to place growth limits on Amsterdam Schiphol are, most probably, a precursor of more widely applied and increasingly rigorous interpretations of the meaning of environmental capacity.

The execution of environmental policy is critically dependent on regulatory intervention impacting both on demand for, and supply of, transport. Evidence suggests that the implementation of environmental policy is driven by threat, 'the dominant influence on a company's investment in environmental technology [being] the need to comply with regulations' (Hitchens, 1997, p. 816). The tenor of such regulation has changed, however, from a command/control to fiscal basis, which assumes that demand - whatever the mode - is exaggerated because transport does not meet its real costs (Stanners and Bourdeau, 1995). While not yet widely applied, European Commission policy on the environmental repercussions is clearly expressed, the 'polluter pays' principle being the common thread linking its various environmental regulations (CEC, 1997a; Hitchens, 1997). In other words, fiscal instruments should be employed in ensuring that transport users pay the full costs of their actions, the objective being one 'of indirectly influencing the supply of transport or the demand for it' by market mechanisms (Button, 1994, p. 128). The Aviation Environment Federation (1995), for example, advocates pricing discrimination in favour of more efficient and larger long-haul aircraft, a strategy which would optimize airport capacity while exploiting air transport's incomparable advantages for intercontinental travel. Again, the Commission is considering a kerosene tax on aircraft fuel.

Any market-oriented initiative to address the interaction between airport capacity and environmental issues in Europe is rendered more complex, however, by the ways in which policies and legislation emanate from - and interact at - a variety of scales and agencies, ranging from globally-binding agreements, through the Commission and individual Member State governments, down to the micro-level of an individual airport and its local planning authority (*Figure 3*). Noise, for example, is a global issue experienced at the scale of the immediate airport locality, also the scale at which complaints about the effects of aircraft engine emissions on health are most frequently expressed. At various stages in this regulatory hierarchy, however, there are missing stages, which, in turn, open up increased opportunities for unilateral action at the

supranational, national or local scales. For example, the failure of ICAO to agree international post-2002 noise limits, when Chapter 2 aircraft will finally be banned at EU airports, has encouraged the Commission, Member State governments and individual airport operators to introduce their own noise rules and surcharges in reaction to more localized pressures. Thus the Commission's consultation paper, *Air Transport and the Environment* (CEC, 1998), states bluntly that further improvements are required on noise and emissions to ensure the sustainable development of air transport.

Such regional initiatives are inherently unfair to the airlines involved, subjecting them to penalties which do not necessarily apply to their global competitors. Moreover, their effect is compounded by individual local restrictions, for example on Chapter 2 aircraft, the incidence of which, in turn, may reflect factors such as the fleet composition of an airport's major users. German airports tended to introduce stiff penalties on older aircraft once Lufthansa had a Chapter 3 compliant fleet, whereas Dublin, for example, continues to suffer Ryanair's hush-kitted Chapter 2 Boeing 737-200 fleet. Freight airlines in particular have been targeted by locally devised noise restrictions, as for example at Nuremberg and Liège (*Flight International*, 1998), partly because they fly almost exclusively at night, often with older, hush-kitted aircraft that are only marginally Chapter 3. Again, the lack of binding global agreements, and - despite a lot of research - a failure to fully understand the effects of high-altitude emissions and contrails on global warming and ozone depletion, may culminate in unilateral action on Nitrogen Oxide (NO<sub>x</sub>) limits. In addition, and in common with several Member State governments (including the UK), the Commission lacks an integrated environmental management policy with regard to transport in general. Nor - excepting DGIV's attempts to regulate slots and their contested ownership - has it formulated any strategy to deal with airport capacity constraints, the principle of subsidiarity, that competence be exercised at the lowest level - as near to citizens as possible, thereby maximizing flexibility and local discretion, apparently applying to airport capacity issues.

#### *The airport operators and society at large*

This mesh of different scales and the gaps in the regulatory hierarchy, combined with the ineffectual nature of some legislation, the array of motives involved, and the absence of centralized policies (the TETN excepted), which might reconcile the demand for air transport, its capacity constraints and environmental concerns, ensure that decisions on airport capacity are often made at the local level in agreements between an individual airport operator and its immediate planning authority. It is generally the case that planning permission for capacity increases depends on operators providing an integrated, locally-acceptable resolution to the entire suite of environmental externalities associated with air transport. Compliance with environmental regulations alone is not a sufficient strategy for an airport operating company. It has to design and implement a proactive policy that addresses a raft of environmental concerns (*Figure 4*). These include:

- effective monitoring and regulation of aircraft noise on the ground and in the air;
- fiscal penalties on noise offenders and best practice instruction for habitual malefactors;
- night curfews or quotas;
- public transport surface access targets;
- monitoring of airside and landside emissions;
- the reduction of energy consumption in terminals and by airport vehicles;
- the recycling of airport waste;
- monitoring water quality and reducing the impact of contaminants - particularly de-icing fluid and oil - on groundwater;
- measures to limit the visual impact of an airport and its land-use severance effects.

Inevitably, because the airport capacity-environmental tension is so often mediated at the local scale, noise tends to be the predominant source of complaint from communities in airport hinterlands. Ultimately, even the largest intercontinental hub is interacting with a local community and the concerns of its inhabitants, a nexus of

conflict of interests dominated by environmental issues, primarily noise. In 1997, the Dutch government proposed a cap on movements at Amsterdam Schiphol, which ranked fourth in Europe and twentieth in the world in 1996 for passenger traffic. The airport, which has a theoretical capacity of around 650,000 slots per annum, was restricted to only 360,000 slots for 1998, compared to the 400,000 requested by the airlines. At the time of writing, it has just been announced that these limits are to be revised, the airport's capacity being allowed to grow in annual increments of 20,000 slots to a ceiling of 600,000. Environmental protests are likely to follow this decision, even if future runway developments are designed to minimise noise externalities. Schiphol will maintain its tight controls on night flights and also continue to operate its noise 'budget' in which aircraft are given values according to the time of day and type of aircraft (Cameron, 1998). The airport is actively discouraging Chapter 2 aircraft which 'cost' too much, while giving financial bonuses to the quietest aircraft. In this context, it is important to remember that not all aircraft qualifying under Chapter 3 comply equally with those standards. The principal opposition to T5 at Heathrow (the world's most important international airport) is from the surrounding local authorities, who - not unsurprisingly - question the figures put forward by the operator, BAA, and the principal airline user, BA, that, due to the use of larger aircraft, an additional 30 million passengers per annum could be accommodated through a marginal increase in movements.

Local authorities, however, have no direct control over the negotiation of noise standards, which are effectively global agreements (although they are concerned with their effective implementation and monitoring), and thus may be exercised more directly by other manifestations of the adverse impact of airports on their immediate environments. Chief among these is the issue of surface access, and the contribution made by airports to road traffic congestion and pollution. European airport operators increasingly recognize the importance of modal shift to public transport, not only for passengers who may use the airport only infrequently, but also for employees who travel to and from it on a daily basis. All the major UK airports, for example, have ambitious public transport access targets. Heathrow is aiming at 50% for all journeys (compared to the present 34%), Gatwick has a 40% target for passengers by 2000 (now 31%), while Manchester is seeking to increase its current 15% to 25% of all journeys by 2005.

Because capacity - however defined - is related so intimately to local concerns, an airport business can grow, only if it minimizes the impact of its expanding activities on that environment and its residents. The circular problem for the airport operator is that having developed and implemented an environmental policy in order (possibly) to be allowed to expand capacity, the externalities of the resultant growth in air traffic created by that additional capacity may outstrip the benefits of the environmental policy. Consequently, airports have had to develop effective and continuous methods of communicating with those residents, who share Western expectations of an enhanced quality of life. Local protests are also often conflated by concerns over property values in urban areas adjacent to airports. One study of the vicinity of Manchester concluded that noise effects on residential property values could not be separated from a wide spectrum of neighbourhood and environmental variables influencing property values. Although house prices were lower in the noise-affected areas, these properties would still have commanded lower prices, even if they had not been located under the flight-path (Pennington *et al.*, 1990). Subsequently, the Manchester data was re-worked by Collins and Evans (1994) who did find a relatively minor noise component in house values.

#### *The airlines*

While the adoption of a dynamic environmental strategy is clearly a rational decision for EU (and other) airport operators, and is perhaps the most important factor driving their businesses, even if it does not result in any additional capacity, it is readily apparent that another set of tensions exist between airports and their principal customers, the airlines. For the latter, the definition of a rational business strategy within the context of European liberalization includes practices that exacerbate the already heavy pressures



on airport capacity, especially at the largest hub airports on which the major carriers' networks are centred. For some airlines, the preferred environmental policy is probably not to have one; at best, a company will develop an environmental strategy only if it is beneficial in profit terms to do so.

The current actions of European airlines in response to the liberalized aviation market-place are largely incompatible with the precepts of environmental sustainability, and the likelihood that any resolution of the capacity-growth tension can be achieved without curbs on demand. Four factors can be identified, all - possibly excepting the last - impacting negatively on capacity:

- the development of hub-and-spoke systems;
- the dependence on increased frequency of service as the primary strategy in accommodating growth and also its role as the principal competitive weapon;
- the growth of low-cost airlines;
- the development of alliances and code-sharing.

#### 1. Hub-and-spoke systems

The route networks of the largest EU airlines are being reconstructed from radial point-to-point to hub-and-spoke systems. The latter involves a dominant carrier operating synchronized banks - or waves - of flights in which the hub-arrival times of aircraft, originating from cities at the ends of numerous spokes, are co-ordinated into a short time period. After the minimum interval necessary to redistribute passengers and baggage, an equally large number of aircraft departs to the spoke cities. This pattern, which is repeated several times during the day, is essentially a supplier-driven strategy, maximizing the on-line (same carrier or alliance) connections available to a particular airline at the hub airport (Dennis, 1994; Graham, 1995). Hub dominance is a large incumbent's most effective defensive tactic in a liberalized market because, especially when combined with airport congestion and linked to an alliance strategy, it offers the real possibility of pre-empting - or at least controlling - competition at a particular airport. Its efficient operation is dependent upon available runway and terminal capacity to handle the peaks, combined with extensive feeder connections, often employing smaller aircraft operated by regional airlines.

The cumulative effect of EU hub-and-spoke operations is to concentrate traffic at a few airports, inevitably those already most constrained by capacity shortages and largely located in relatively close proximity within the dominant axis. The most important are London Heathrow, Frankfurt, Amsterdam and Paris CDG. The US hub-and-spoke model, with its dominant carrier and dedicated terminals and gates, cannot be replicated fully in Europe, largely because of existing restrictions on airport capacity. Heathrow, for example, has insufficient airport capacity for BA to mount a proper hub-and-spoke system, the carrier depending instead on what might be termed random - or continuous - hubbing, in which a high degree of connectivity is achieved through its sheer volume of flights across the airport. KLM's operation at Schiphol is the most fully developed example of a European hub-and-spoke system, having four major and two lesser waves per day; the hub serves 120 European and 110 long-haul destinations. As 60% of the airline's business comes from transfers across this hub, its desire to expand European market share and the capacity control policy proposed by the Dutch government were obviously in conflict. Although the major European carriers are being forced to develop secondary hubs - BA at Gatwick, Air France at Lyon Satolas, KLM at Milan Malpensa and Rome (through its Alitalia alliance) - because of congestion at their primary bases, they still cannot afford to dilute feed for high yielding intercontinental routes - their most profitable services - which depend on maximizing the incidence of potential transfers across that core hub. In order to achieve this goal, all the major European carriers have established networks of feeder routes increasingly operated by groups of affiliate regional airlines, which have lower cost structures but rarely operate aircraft larger than 120 seats (Graham, 1997b).

Feeder routes usually link a secondary city - which may well be in a different country - to the intercontinental hub. Such services are escalating in number, partly because the widespread introduction of regional jets has created a far more flexible product. Although hub-feed routes are the most valuable services that regional airports

can provide to consumers in connectivity terms, they also increase movements, particularly by smaller aircraft, and inevitably exacerbate airport capacity problems. Although regional aircraft generally require only short runways, almost all major EU airports lack such dedicated facilities, forcing inefficient use of main runways by small aircraft, which also increases ATC problems with aircraft separation. Thus capacity constrained airport operators will seek to rationalize demand for their scarce resource by adopting pricing structures that militate against smaller aircraft. For example, regional aircraft have largely been forced out of Heathrow. One way to obviate the difficulty of hub access is the concept of the airport system in which the feeder - or reliever - airport, used for regional traffic, might be linked to the hub by dedicated train. One such example is Düsseldorf Express (Moenchengladbach), which is being developed as a reliever field for slot-constricted Düsseldorf Rhein-Ruhr. Regional carriers may also opt for (or be forced to use) secondary airports. KLM uk (formerly Air UK), for example, has exploited spare capacity at London's Stansted and City airports, while, more generally, capacity-rich secondary airports - especially those in downtown locations and accessible only to small jets or turbo-props - can provide regionals with competitive niche markets for point-to-point traffic.

The process of hub concentration is being accompanied by an apparently contradictory trend towards dispersal as more secondary cities develop international routes. The liberalization of transatlantic bilateral agreements has produced a 'fragmentation' of that market, in which the proliferation of gateways in North America and Europe means that many more city-pair markets are served direct by smaller twin-jets. This long-haul fragmentation is replicated at the regional scale by the rapid expansion of hub-bypass routes, increasingly serviced by regional jets. Although this dispersal may have beneficial effects for congestion at individual airports, the increased ATMs generated by the additional services compound the negative effects of air transport on global air quality.

## 2. Frequency as an airline strategic tool

As in the United States, it is apparent that the hub-and-spoke system evolving in Europe, contradicts the argument that the projected growth of demand for air transport can, at least in part, be accommodated by the use of larger aircraft. These have better seat/mile costs and do offer a means of enhancing capacity at given airports without increasing departures; they do, however, create more noise. But only one major European carrier - BA - is pursuing this strategy, largely reconstructing its Heathrow-based fleet around aircraft with a minimum capacity of around 180 seats. Heathrow already has the highest number of passengers per ATM in Europe and the case for T5 is that this momentum can be maintained.

That BA is the exception to the rule is underlined by the statistic that almost 90% of the aircraft added to the fleet serving intra-European schedules since 1987 are less than 170 seats: 'Airport congestion has had only a modest influence on airline fleet requirements' (Boeing, 1998, p. 28). The implications for airport capacity are profound. It is readily apparent that the hypothetical use of larger aircraft conflicts with the evidence that 'airlines will continue to pursue strategies that accommodate growth primarily through additional frequencies' (Boeing, 1997, p.3). Boeing estimates that 70% of aircraft deliveries over the next decade will be single-aisle models (mostly less than 200 seats), which will account for 71% of the world fleet by 2006, dropping only marginally to 69.1% in 2016. Such projections underline the fragility of any argument that growth can be partly accommodated in larger aircraft. BA can pursue its strategy of increasing aircraft size at Heathrow, only because routes incapable of supporting larger aircraft at a sufficient frequency are being diverted to Gatwick, or even Manchester and Birmingham. The Boeing 737s displaced from Heathrow have largely gone to Gatwick but, then, it too is dependent on increasing aircraft size to meet its projected capacity targets.

The airline fixation with frequency as the primary means of accommodating growth stems from its role as a - if not *the* - primary form of non-price competition. The mix of aircraft in European airline fleets is being driven by the need to maximize frequency in the competitive market-place, market share being maximized by frequency

share, which essentially demands smaller aircraft. Further, competitive market entry demands a matching of frequency with that of the incumbent carrier(s). Thus British Midland Airways, which in early 1998 began service between Manchester and Heathrow in competition with BA, is offering eight daily frequencies but using only 130 seat Boeing 737-500s. In one sense, this is an indefensible use of very scarce capacity in one of the world's most congested airport systems on a city-pair that should be served by HSTs. In another, however, it represents a rational business decision that reflects the airline's integration as a feeder into the operations of Lufthansa and SAS. Nor are long-haul services exempt from the frequency strategy, some airlines on the North Atlantic, for example, having down-sized from Boeing 747s to smaller twin-jets operating at higher frequency. The importance of frequency is compounded by evidence that it is high-yield business-class passengers who are most sensitive to this factor. Consequently, most European carriers have linked frequency and status products, further reducing the capacity of their aircraft to install separate business-class cabins and/or seating for those paying for premium tickets that maximize frequency benefits, including the ability to switch flights. The problem is that this behaviour, which constitutes rational behaviour for the individual airline, is incompatible with wider notions of environmental sustainability.

Because frequency has evolved as such a key strategic weapon for airlines in the competitive market-place, aircraft size has actually declined in certain markets. Thus while Air France has radically enhanced frequency on the heavily contested domestic trunk routes between Paris, and Marseille, Nice and Toulouse as its response to competition from AOM French Airlines and Air Liberté, it is doing so using aircraft no larger than 180 seats. As late as the mid-1990s, the most common aircraft on these routes were wide-bodied Airbus A300s of Air Inter, carrying over 300 passengers. One result is that the average number of passengers per aircraft movement at Paris Orly (the principal French domestic airport) dropped from 126.8 in 1995 to 108.9 in 1996.

Although consumers benefit from more frequent services, the negative environmental effects of the widespread use of relatively small aircraft (defined as the sub-optimal use of scarce capacity resources) are compounded by unimpressive load factor statistics. Those of European Regions Airline Association members have scarcely changed during the past decade, averaging only 53.1%. Again, although long-haul statistics have improved, at around 64%, the short-haul cross-border passenger load factors of AEA members are scarcely higher now than they were in the mid-1980s (AEA, 1998). The combination of frequency as a competitive weapon with relatively modest load factors means that the 'slot productivity' of many major European airports rarely exceeds 100 passengers/commercial aircraft movement. Airlines, moreover, are forced to try and sell surplus capacity through special fares and promotions. Such tactics, of course, simply encourage increased mobility and the pressures on scarce resources. The operation of Frequent Flyer Programmes (FFPs) has a similar effect in that these encourage people to consume mobility which they believe to be free. Perhaps as much as 10% of traffic on some airlines is accounted for in this way, leading to suggestions that FFPs should be taxed or even banned.

### 3. Low-cost airlines

While the advent of aggressive US-style low cost/'low-no frills' airlines such as Dublin and Stansted based Ryanair, Virgin Express at Brussels, easyJet at Luton and the BA subsidiary, Go, at Stansted, has been hailed as one of the major benefits of European liberalization (clearly so for passengers), their aggregate effect has again been to increase mobility. Essentially low-fare, point-to-point operators, dependent on low costs and high capacity, these airlines may effectively be competing with more conventional transport modes - classic rail, ferry and long-distance coach - as much as incumbent airlines. Their expansion demonstrates that price can create markets, albeit largely located within the regions already most densely served by existing carriers. For access to cheaper and available capacity, the low-cost operators may use lesser airports close to major cities, but their overall impact is to contradict principles of sustainability in that they contribute to air transport congestion in the EU's dominant axis, while

encouraging growth in mobility and adding to aggregate air transport emissions and noise.

#### 4. Alliances and code-sharing

Hub dominance, especially when combined with airport congestion, offers the real possibility of pre-empting - or at least controlling - competition. Moreover, it is a strategy increasingly linked to another - the tactical airline alliance. The EU's hubs are also becoming the European centres of the global alliances being orchestrated by the world's most powerful airlines (Schiphol, for example, is the European base for the KLM-Northwest Airlines grouping). Through acquisition, negotiation and the increasingly widespread use of franchising, almost all the most powerful European carriers have constructed intra-continental coalitions which, in turn, form part of wider global agreements. There are very few small wholly independent airlines in the EU and most entrants soon enter into code-sharing, franchising or other agreements with the majors. While such strategies are aimed at subordinating the free market to the interests of the largest airlines, there may be, perhaps, an inadvertent environmental bonus. By their very nature, alliances curb capacity growth and, hypothetically, should allow more efficient use of existing resources. This may not be good for competition but adopting a different perspective, unconstrained competition in air transport is wasteful of investment and resources, including non-renewable hydrocarbons and scarce airport capacity. It also increases the externalities of air transport, particularly atmospheric emissions, noise and terrestrial congestion. It remains to be seen if the rapidly escalating incidence of alliances has a beneficial impact on airport capacity congestion but this is the only current airline tactic in a competitive market-place which offers any such potential.

#### **Conclusions: environmental sustainability, airport capacity and European air transport liberalization: towards a resolution?**

The preceding discussion has demonstrated that the different players in the air transport industry, making what they regard as the most feasible and judicious decisions regarding their own business and consumer interests, are in conflict with each other. As many as five sets of essentially irreconcilable tensions define the fault-lines in the relationship between environmental sustainability and the air transport industry in Europe. First, any acknowledgement of the relevance of environmental sustainability requires acceptance of the idea that 'infinite mobility is not infinitely good' (Bleijenberg, 1995, p. 14), which is the very antithesis of the strategic policies adopted by airlines in a deregulated market-place. Secondly, even though a number of airports will remain capacity-rich, the aggregate projected growth rates of air transport in Europe cannot be accommodated within existing or planned aggregate airport capacity, particularly when the demand for air transport is geographically concentrated in those regions defined by the highest GDP/capita, a spatial pattern unlikely to alter significantly. Thirdly, airport capacity is essentially being driven by environmental criteria, which implies - *de facto* - if not *de jure* - constraints on air traffic growth. Fourthly, and in marked contrast, the business strategy of the European airline industry in its newly competitive ethos demands network and frequency characteristics, which exacerbate the demand for airport capacity at a rate even greater than that required by aggregate growth in passenger traffic. In these respects, airlines are not behaving with due regard for environmental factors, but the corollary is that it would be commercially suicidal for any one firm so to do. If, however, the purpose of competition is to eradicate competitors in the longer-term, the processes of globalization in the airline industry might be viewed as beneficial because their ultimate aim can be interpreted as generating higher profits from capacity control. Finally, the liberalization policy for European air transport is arguably at odds with the commitment to 'sustainable mobility' supposedly at the heart of European transport policy.

In apparent confirmation of the argument that policies to mitigate the environmental impacts of transport are subsumed by countervailing market developments, the EU lacks an integrated air transport and environmental policy. The Third Package prioritises competition at the expense of any other goals of social

solidarity, cohesion or environmental sustainability. Air transport policy is for air transport alone, failing to address either the integrated nature of transport itself, or the broader concerns and demands of society. This failure to produce an air transport policy, which effectively addresses the wider implications of the mode's activities, obviously opens up the possibility of other institutional actors becoming involved through the application of piecemeal standards, which, ironically, undermine the supposedly 'level playing-field' being sought through competition policy. It would be foolish of the air transport industry to regard unilateral actions such as the capping of Schiphol as isolated cases, for they are more likely to be exemplars that will be followed elsewhere, albeit in a haphazard fashion because of the failure to agree post-Chapter 3 environmental standards. Society is moving towards an aggregate acceptance that infinite mobility cannot be sustained, even if individual people and companies are not yet prepared to modify their behaviour accordingly. But the tenor of EU environmental policy is explicit; the 'polluter pays' principle - if properly applied - implies an internalization of environmental costs through increased direct and indirect taxation on transport use and more stringent regulations on noise and emissions. The environmental externalities of air transport are thus seen as a market failure to be redressed through market mechanisms. The demand for mobility will be suppressed by measures aimed at making air transport pay those 'real' costs. Against this, however, is the important point that any pricing mechanism for reducing demand is inequitable in that business travellers and the wealthy are penalised far less than the members of society less able to pay.

Within that scenario, what actions can the stakeholders in the air transport industry take? Some additional infrastructural capacity will be built but it will be nowhere near sufficient to meet projected growth. In a rational world, that scarce resource would be used more effectively through the deployment of larger aircraft and high-capacity one-class cabins (in a very real sense, the European IT industry already offers a sustainability model) although - as we have seen - that would flatly contradict airline economics. Airport charge regimes can penalize small aircraft although this actually discriminates against accessibility to peripheral regions and regional airlines. A more equitable solution might be to link airport charges to load factor.

Traffic diversion offers some potential, given that the impact of capacity problems varies spatially and the large number of capacity-unrestricted airports in the EU, not all of which are sited in remote locations. It is an overstatement to claim that 'the future is to fly from an airport that no-one wants to fly from to an airport no-one wants to fly to' (*Air Transport World*, May 1996, p. 68). Many travellers are happy to use secondary airports for point-to-point journeys, especially if price compensates for any inconvenience. Airports such as Manchester and Lyon Satolas can develop credible long-haul and connecting scheduled networks, while IT companies are prepared to use any regional airports servicing sufficient demand. In addition, general aviation activities could be concentrated at reliever fields. However, neither traffic diversion or modal shift to HSTs reduce aggregate levels of mobility.

Ultimately, however, none of these tactics - or even all of them - can solve the capacity versus growth equation. Eventually, EU policy-makers must address the problem that aggregate mobility in Europe, air transport included, exceeds the environmental optimum. It is unlikely that laissez-faire attitudes, which disregard the need for an integrated environment-transport policy, will prevail, no matter how much the airlines might want this. In many ways, the environmentally-driven strategies of airport operators are an exemplar of what is to come. The ethos of the times is also against traditional command/control environmental policy. Instead, we have the Schiphol scenario in which the airport business is allocated overall limits but then organizes its own activities within those constraints. Its effectiveness does depend, as Bleijenberg (1995) argues, on airlines renouncing their apparent preferred objective that there should be no environmental policy at all. Ultimately, any resolution of the manifest tensions between environmental sustainability, airport capacity and European air transport liberalization, depends on the development and application of common standards. Only then can the behaviour of an individual airline be commensurate with

the wider interests and goals of society, without that company being penalized in terms of competition.

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**Table 1** Declared hourly runway capacities for summer busy periods. Source: CAA (1998, p. 46).

Airport	1993	Capacities 1995	1998	Median 1998
<b>Single Runway</b>				34.5
Gatwick	36-45	40-47	42-48	
Manchester	41	42	45-47	
Geneva	30	30	35	
Düsseldorf	30	30	34	
Milan Linate	24	22	32	
Athens	30	30	30	
<b>Converging Runways</b>				52
Stockholm Arlanda	63	66	70	
Zurich	60	60	66	
Vienna	30	45	54	
Madrid	35	35-50	50	
Barcelona	28	30	47	
Hamburg	40	42	45	
<b>Parallel Runways</b>				76
Heathrow	77-79	77-81	75-84	
Paris CDG	76	76	76-84	
Copenhagen	74	76	81	
Munich	68	70	80	
Frankfurt	68	70	76	
Paris Orly	70	70	70	
Brussels	53	60	64	
Rome Fiumicino	50	56	63	
Milan Malpensa	30	30	26	



Table 2 Maximum hourly movements at some principal EU airports.<sup>1</sup> Source: *Rolls-Royce Market Outlook*, 1997.

Airport	1996	2015	%age increase
Amsterdam <sup>2</sup>	86	140	63
Athens <sup>3</sup>	32	80	150
Barcelona	30	55	50
Brussels	60	80	33
Copenhagen	69	80	16
Düsseldorf <sup>2</sup>	36	65	81
Frankfurt	70	100	43
London Gatwick	43	48	12
London Heathrow	82	85	4
Madrid	43	50	16
Munich	70	110	57
Paris CDG	76	120	58
Paris Orly	70	80	14
Rome Fiumicino	56	70	25
Stockholm Arlanda	66	100	52
Zurich	60	100	67
Median			47.5

<sup>1</sup> Projections assume absence of environmentally-driven limits on movements.

<sup>2</sup> Theoretical projections; both have current caps on ATMs for environmental reasons.

<sup>3</sup> Assumes completion of new airport at Spata.

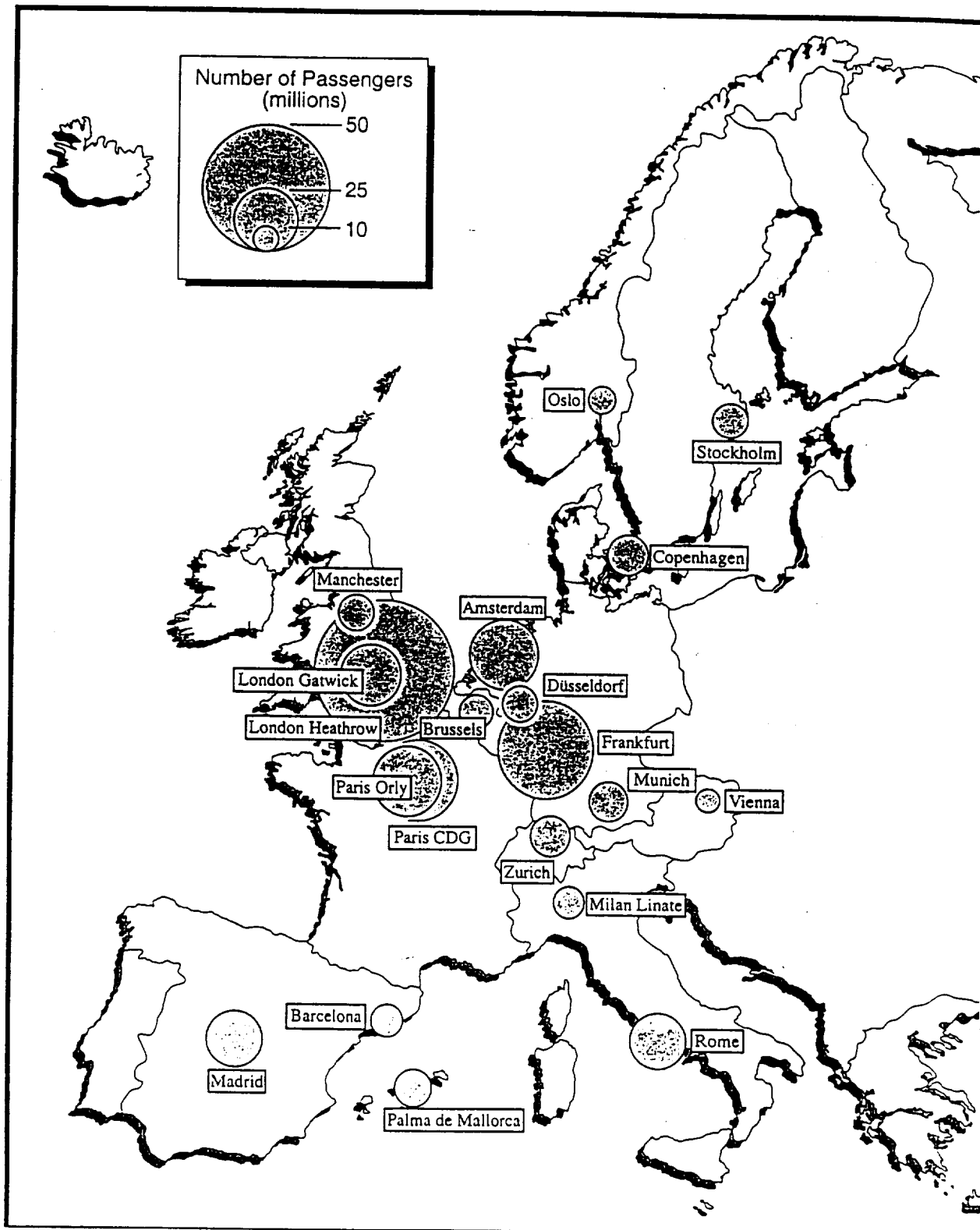


Figure 1 Principal EU airports (plus Norway and Switzerland), 1996, by million passengers handled. Source: Airports Council International, Geneva.

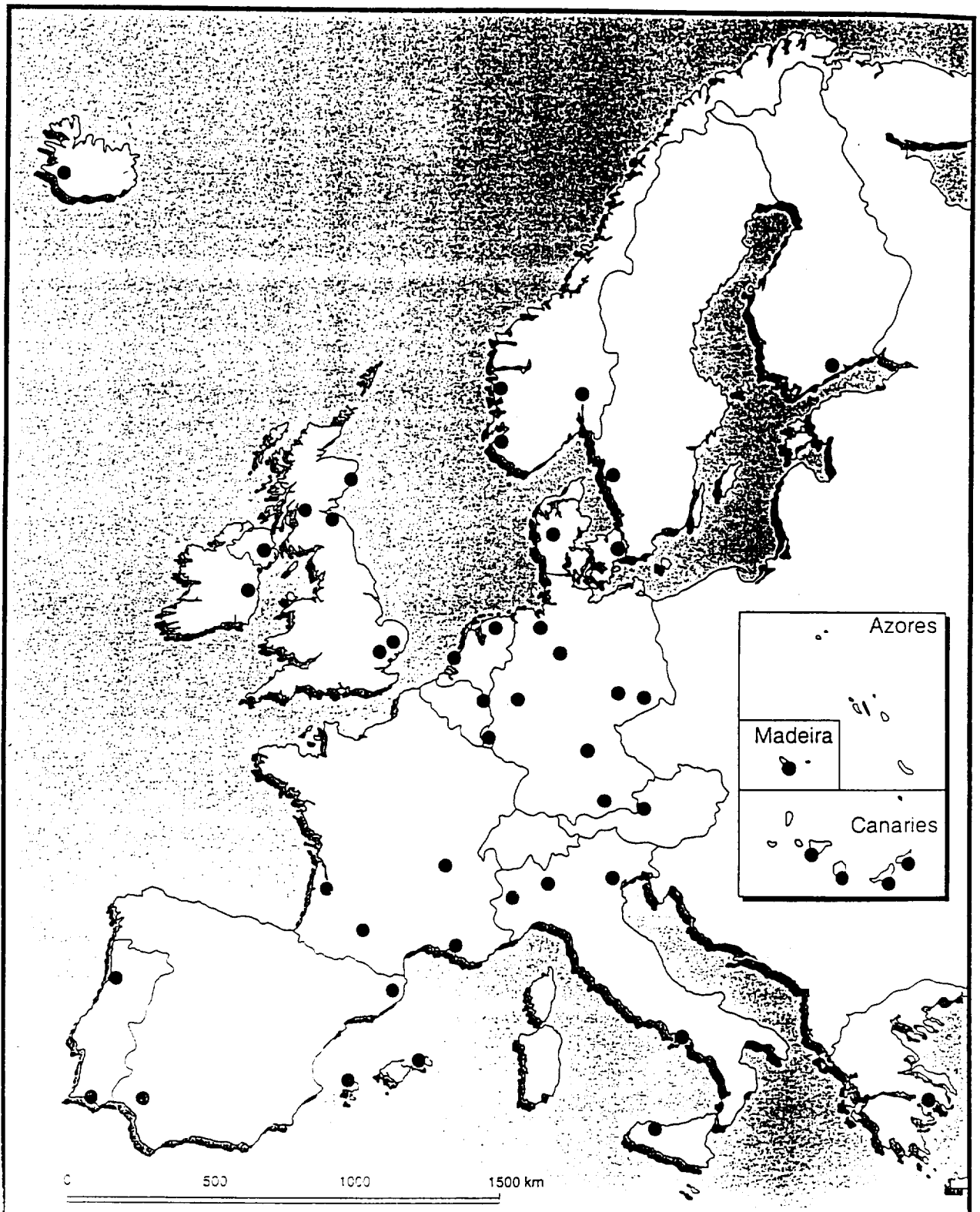
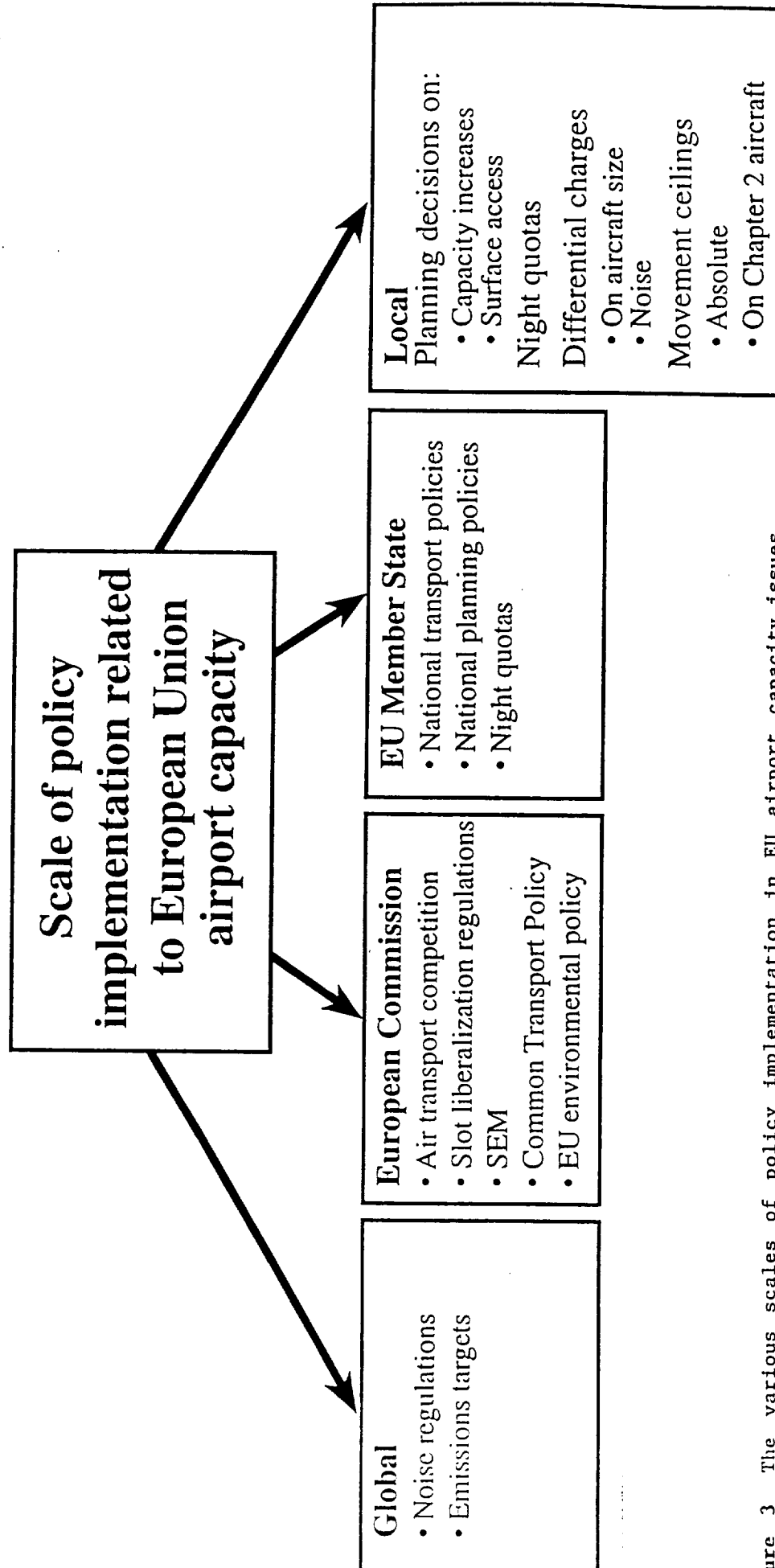
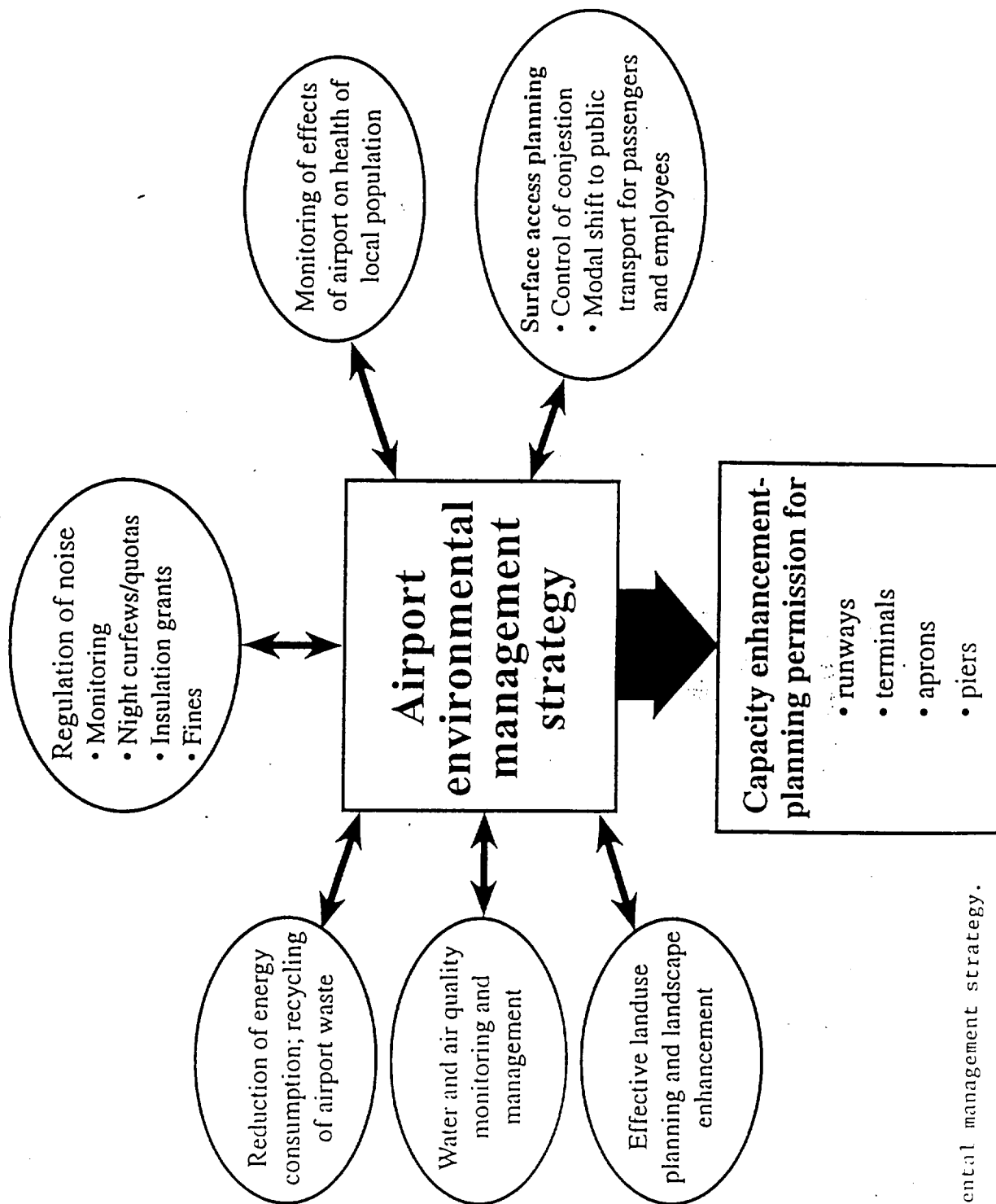


Figure 1. Distribution of the species (black dots) in Europe (Iceland, Norway and Switzerland) with the distribution of the species in the foreseeable future. Source: Simon



ure 3 The various scales of policy implementation in EU airport capacity issues.



# **Civil Aviation Development in the Taiwan Area**

By

**Yu-Chun Chang<sup>1</sup> and Dr. George Williams<sup>2</sup>**

Air Transport Group,  
College of Aeronautics,  
Cranfield University,  
Bedfordshire MK43 0AL, UK

Fax: +44 (0) 1234 752207

Tel: +44 (0) 1234 750111 ext. 2242

E-mail: [y.chang.1998@cranfield.ac.uk](mailto:y.chang.1998@cranfield.ac.uk)

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1. Yu-Chun Chang is a doctoral student at the Air Transport Group, College of Aeronautics, Cranfield University.

2. Dr. George Williams is a senior lecturer at the Air Transport Group, College of Aeronautics, Cranfield University.

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Bedfordshire MK43 OAL, UK  
Fax: +44 (0) 1234 752207 Tel: +44 (0) 1234 750111 ext. 2242

## **Abstract**

Over the past two decades, demand for air transport in Taiwan has grown rapidly, partly in response to the economic development of the country, but also as a result of the worsening quality of the highway and rail transport systems. Since the deregulation of domestic airline services in 1987, the number of routes operated has increased from 20 to 41 and the national fleet from 75 to 186 aircraft. Over the period, domestic scheduled airline traffic has increased at an average annual rate of 18.4%, whilst international scheduled airline traffic has grown at 10.3%. In 1997, the number of domestic air passengers reached 18.7 million and international air passengers 17.1 million. These large increases in demand have resulted in a great impact on the use and operation of airport facilities.

The area of Taiwan is slightly smaller than that of the Netherlands, being some 36,000 sq. km (14,000 sq. miles). It is 394 km (245 miles) long and 144 km (89 miles) at its broadest point. Seventeen airports serve civil aviation, ten of which are located on the mainland and seven on off-shore islands. How is it that a country of this limited geographical area can generate over 35 million air passengers and 1.2 million tons of air cargo annually?

This paper reviews and analyses the existing airport facilities, provides a comprehensive transport demand forecast and examines the progress and recent development of Taiwan's airline industry. It is based on extensive research carried out by the authors and a team from Institute of Transportation, Ministry of Transportation and Communication, Taiwan between 1995 and 1997. This included desk research, a passenger survey and interviews with the airport authorities. It has been updated by the authors to take account of more recent developments, especially the "Open Skies" agreement with the US and the various airline alliances that have occurred involving international and domestic carriers.

# Civil Aviation Development in the Taiwan Area

## 1. Introduction

### 1.1 Area

The area of Taiwan is slightly smaller than that of the Netherlands, being some 36,000 sq. km (14,000 sq. miles). It is 394 km (245 miles) long and 144 km (89 miles) at its broadest point. The eastern side of the island is dominated by a north-south mountain range rising to 13,100 feet. The western side of the island is a fertile plain through which the country's only motorway links the capital Taipei in the north to Kaohsiung in the south. Surrounding Taiwan, there are many small islands including the Penghu Islands, the Kinmen Islands, the Matsu Islands, Orchid Island and Green Island. The need for fast links between major cities in Taiwan and between these small islands and Taiwan creates opportunities for the air transport industry.

### 1.2 Population

The population of Taiwan was a little over 21 million in 1997. It has increased at an average annual growth rate of 1.2% since 1983, when it totalled 18.7 million. After 1995 however population growth declined to less than 1.0% per annum, reflecting the fact that Taiwan is reaching its saturation level in terms of people (see Figure 1-1).

### 1.3 GDP

Taiwan's economic structure has changed considerably since the mid-1980s. High-tech products have constituted a sharply increasing percentage of exports. Over the same period, the Gross Domestic Product (GDP) increased sharply from US\$52.4 billion in 1983 to US\$283.3 billion in 1997, with an average annual growth rate of 12.81%. Economic growth between 1986-1989 was particularly high, averaging more than 20%, with a peak of 35% achieved in 1987 (see Figure 1-2).

## 2. Air Transport in Taiwan

### 2.1 Airports

There are seventeen airports that serve civil aviation in the Taiwan Area, ten of which are located on the mainland and seven on off-shore islands (see Figure 2-1).

Of the seventeen airports, two are international airports and fifteen domestic. Only CKS International, Kaohsiung International and four off-shore island airports (Green Island, Orchid, Wangan and Chimei-yu) are exclusively devoted to civil aviation, with the remaining eleven domestic airports shared with the military (see Table 2.1).

### 2.2 Airlines

The first privately owned air carrier, Foshing Airlines, was established in 1951. FarEastern Air Transport and China Airlines followed in 1957 and 1959 respectively. Taiwan Airlines,



Formosa Airlines and Great China Airlines were set up in 1966. By the Mid-1980s, however, there were only four air carriers actually operating in Taiwan. China Airlines and FarEastern Air Transport operated on domestic trunk routes, while Formosa Airlines and Taiwan Airlines focused on off-shore islands routes. Foshing Airlines by then had concentrated on the profitable air catering business and also worked as general sales agent for foreign airlines.

After the proclamation of deregulation of Taiwan's air transport industry in 1987, more and more new companies entered the market. Makung Airlines was set up in October 1988. It was later renamed UNI air when 51% of its shares were sold to EVA Airways. After reorganization of their Board members, Great China Airlines and Foshing Airlines resumed their domestic air transport services in 1988. Aiming at international operations, Foshing Airlines changed its identity and was renamed TransAsia Airways. China Asia Airlines was established in 1989 and renamed U-Land Airlines when the U-Land Construction Group took over the airline in 1994. EVA Airways was established in 1989 and entered into the domestic market in October 1994. Mandarin Airlines, a subsidiary of China Airlines, was formed to operate international routes in 1991. Mandarin Airlines is the only airline that does not operate domestic route. A summary of Taiwan airlines' fleets in 1995 is provided in Table 2.2.

### **2.3 Domestic Airline Market Supply**

Table 2.3 shows how the supply has changed over the past eleven years.

- i). Number of Airlines: domestic airlines have increased from 4 in 1987 to 9 in 1997.
- ii). Destinations Served: between 1987 and 1997, these have increased from 13 to 16.
- iii). Service Routes: between 1987 and 1997, these have increased from 20 to 41.
- iv). Frequencies Operated: the total number of flights has increased from 76,580 in 1987 to 286,170 in 1997.
- v). Seats Provided: these have increased from 4.2 million in 1987 to 28 million in 1997.

### **2.4 Domestic Air Transport Deregulation Policy**

The Civil Aviation Industry Administration Rules announced in 1949 gave the Civil Aeronautics Administration (CAA) of Taiwan the authority to:

- i). Control entry into the industry,
- ii). Control entry into new or existing routes,
- iii). Control exit by requiring approval before cessation of service to a point or on a route,
- iv). Regulate fares,
- v). Control mergers and intercarrier agreements,
- vi). Investigate deceptive trade practices and unfair methods of competition.

In October 1987, the Ministry of Transportation and Communication (MOTC) proclaimed the open sky' policy for the domestic air transport industry. The policy mainly focused on providing a looser control on entry into the industry and of entry into new or existing routes. The fare control rule was modified in 1989 to allow airlines to have more freedom to discount rates.

In 1990, the MOTC prevented further entry into the industry, because there were too many domestic airlines operating in the market.

### **3. Demand for Air Transport**

#### **3.1 Competition with Surface Transport**

The highway is the most popular transport mode in Taiwan due to the close proximity of the cities. In 1980, 2,060 million passenger journeys were undertaken by road, accounting for 93.5% of total passenger traffic, while air transport carried only three million passengers, equivalent to 0.14% of total traffic. However, the highway system has become saturated due to the rapidly increasing use of private cars. The situation is at its worst when there is any public holiday. People need to spend more than twice the amount of time on journeys during the peak season. It is very crowded on the trains at this time as well, owing to capacity limitations of the existing rail network. Any further development of the air transport industry would thus have the obvious effect of easing the congestion on surface transport. As a consequence, the air system increased its market share to 1.23% of total traffic in 1996, while the highway market share declined to 87.53%. The changes in market share of domestic transport modes are shown in Table 3.1.

#### **3.2 Demand for Domestic Passenger Air Transport**

The domestic air transport industry has experienced a growing trend since 1971 (see Figure 3-1), when the number of passengers carried by airlines was just over one million. Between 1972 and 1978 the industry grew rapidly with an average annual growth rate of 25.35%. In 1978 the number of passengers carried by airlines was nearly four million, about four times greater than the figure of seven years earlier. However, after 1979 the demand for air transport declined continuously for four years at an average rate of 8.36%. This was mainly caused by improvements in the ground transport system, including the completions of the first motorway, northeast railroad and the electric powered railway system. The improvements in the ground transport systems led passengers away from the airline industry. In 1980 the passengers carried by airlines decreased by 19%, while those carried by the railway system increased by more than 8%. The substitution effect of demand between air and ground transport in Taiwan was thus apparent.

Between 1985 and 1986, the passenger demand again declined. The main reason for this was that China Airlines had put most of its resources into expanding its international routes. For the domestic market, the airline kept only three B737 to operate six domestic routes. The capacity of these routes thus remained almost unchanged for many years. The other reason was that FarEastern Air Transport had problems due to confusion among the main shareholders which affected the operation of the airline. Most of the B737s operated by the company were introduced about 20 years ago. As a result of the problems experienced in the 1980s, there was no updating of the fleet. After 1987, the domestic air transport industry of Taiwan returned to an era of rapid growth following deregulation. The demand for air transport increased sharply from 1987 to 1997, with an average growth rate of 18.35%.

### **3.3 Demand for and Supply of Domestic Passenger Air Transport**

One of the major reasons for deregulation was to develop the capacity of domestic air transport so as to ease the congested ground transport in Taiwan. This aim has been achieved in the deregulation era. Under deregulation, airlines may easily enter into new markets and increase the capacity of routes.

The demand for domestic air transport increased 27% in 1987, whilst the capacity of the industry increased by only 17%. The gap between supply and demand resulted in a high seat load factor, reaching more than 80% (see Figure 3-2). With such a high occupancy, passengers frequently experienced difficulty in booking seats on their desired flights. During the peak season, especially Chinese New Year, passengers had to queue for hours to buy tickets. It was apparent that the industry's supply was far below the public's demand. This was the main reason behind the government's decision to deregulate domestic air transport.

After the deregulation of domestic air transport, the growth rate of annual available seats exceeded the growth rate of annual passenger demand. This was mainly due to the fact that airlines started to introduce new larger size aircraft into the market. Total available seats numbered 4 million in 1987, but by 1997 had increased to 28 million. The total increase in annual available seats was nearly 700% over the ten-year period. The number of available seats has boomed since 1991. The average growth rate of annual available seats has been nearly 24% over the last six years. This rapid increase in supply resulted in excess capacity and created a more competitive market environment in the industry.

### **3.4 Competition at the Route Level**

In 1987, more than 95% of routes were operated by one or two carriers. Of the 20 routes operated, eight were served by one carrier and eleven were operated by two carriers (see Table 3.2). Since the new carriers entered into the market the situation has changed. By 1996, the routes served by one carrier had declined to 23% of the total number of routes served, whilst the routes served by four or more carriers had increased to 20%. It is clear that the operation of the air transport industry before deregulation was either monopolistic or duopolistic. The domestic air transport industry after deregulation however is much more competitive. The increased competition in the market may be explained by the increasing number of airlines. The continued existence of monopoly in 1997 is mainly caused by the expansion of operations to smaller airports. These small airports usually have only short runways, which require airlines to operate aircraft with short takeoff and landing capabilities. This generates a certain kind of natural barrier to other carriers who do not have such type of aircraft. For example, Formosa Airlines is a monopolistic operator on the Taipei-Matsu route, because its Dornier 228 is the only aircraft allowed to operate on such a short runway as that at Matsu. This kind of technical barrier cannot exist for long however. When the runway extension program is completed, more airlines will enter the market.

### 3.5 Market Share of Carriers

Prior to deregulation there were only four carriers operating domestic routes. China Airlines and FarEastern Air Transport were the two major players operating the trunk routes in 1986, carrying nearly 90% of the total passenger traffic. Formosa Airlines and Taiwan Airlines were two minor operators who focused on the thin routes and carried the remaining 10% of traffic (see Table 3.3).

FarEastern Air Transport was the most important domestic air carrier, with a market share of over 50%. Confusion among its main shareholders adversely influenced the company's fleet update however, leading to a decline in its market share from 57% in 1986 to 29% in 1997.

As Formosa Airlines and Taiwan Airlines operated mainly on the thin routes linking small islands with Taiwan, they avoided head on competition with the big two carriers. Small propeller aircraft were widely used by both these airlines to suit the operational requirements of the short runways on the islands. TransAsia Airways entered the market in 1988 and grew rapidly. Its market share was only 1% in 1988, but by 1995 it had over 27%. Since then its share of traffic has declined to around 22%. Great China Airlines and Makung Airlines were the other two major airlines to enter the domestic air market in 1989. Each had their market share increase from less than 5% in 1989 to more than 10% in 1997. U-Land Airline achieved notoriety in Taiwan when in 1994 the U-Land Construction Group took over China Asia Airlines, adopting a marketing strategy to "fly Taipei-Kaohsiung route with one NT dollar". The strategy proved very successful for U-Land Airline as it was able to increase its market share from 0.057% in 1994 to 6.11% in 1997.

### 3.6 Market Shares by Route

The Taipei-Kaohsiung route is the busiest consistently accounting for more than 30% of the domestic market over recent decades (see Table 3.4). Before 1992, the Kaohsiung-Makung route was the second busiest route as a result of Makung, the largest off-shore island in the Taiwan Area, being poorly served by ferry. After 1992, demand on the Taipei-Tainan route increased sharply, raising it from being the fifth to the second busiest route in the domestic market.

The Taipei-Kinmen route is the other one which has grown rapidly. After deregulation of services to Kinmen Island in 1990, the demand for air transport increased sharply with the route's overall market share rising from 0.52% in 1987 to 5.45% in 1995.

### 3.7 Air Fares

Air Fares remained under the CAA's control after deregulation. Airlines had to get CAA approval before issuing any new fare. Air Fares have been raised three times to cover increased operational costs over the past ten years (see Table 3.5 and 3.6). Between 1990 and 1993 fares on most routes increased by around 12%, reflecting the effects of inflation, although in certain cases there was no change in the rate charged. In the period 1993-1995, fare

increases varied between 4% and 11%.

In December 1995, the CAA proclaimed a change to air fare policy to allow airlines to have more freedom to adjust their fares freely within a maximum discount rate of 30%. On special occasions, such as the inauguration of a new airline, the introduction of a new aircraft, the operation of a new route or a company's anniversary, airlines have the right for special promotions within a maximum discount rate of 50% for a two week period. Airlines need to report to the CAA for such special promotions 30 days before the promotional date. This became the first occasion that the CAA loosened its control on air fares since deregulation.

## **4. Supply of Airports**

### **4.1 International Airport Facilities**

Table 4.1 lists the major facilities of the two international airports in Taiwan. There are two parallel runways at CKS International Airport, both of which are more than 3,300 meters in length. Currently there are 22 in-contact and 8 remote parking stands available for passenger aircraft, with 12 parking stands provided for the cargo terminal.

The other international airport at Kaohsiung operates with one runway. It has 12 in-contact parking stands at its passenger terminal and 4 parking stands at the cargo terminal.

### **4.2 Airport Traffic Data**

CKS International Airport is the most important international airport in Taiwan, handling 107,822 aircraft movements, 14 million international passengers and one million tons of international cargo in 1997 (see Table 4.2).

Taipei Airport is the most important domestic airport in Taiwan, with 187,998 aircraft movements, 15 million domestic passengers and 39,596 tons of domestic cargo handled in 1997.

Kaohsiung International Airport is the second most important airport for domestic services, with more than 9 million passengers and 21,057 tons of cargo handled in 1997.

### **4.3 Changes in International Airport Operations**

Between 1990 and 1997 traffic growth at CKS International Airport was moderate, with a 9.82% annual increase in aircraft movements, a 6.84% annual rise in international passengers and a 9.19% annual increase in international cargo (see Table 4.3 to 4.5).

Traffic at Kaohsiung International Airport has risen sharply since 1990. The number of aircraft movements was only 4,000 in 1990, but by 1997 this figure had increased to nearly 27,000. International passenger traffic increased nearly four times between 1990 and 1997, with an average growth rate of 21.33%. The average growth rate of international cargo was 18.95% between the same years.

#### **4.4 Changes in Domestic Airport Operations**

Most of the domestic routes serving Taipei are handled at Sung Shan Airport, located 5 kilometers north of the city centre. Sung Shan is a hub airport and is the busiest for domestic routes, serving more than 15 million passengers in 1996.

Traffic at Taichung, Chiayi, Tainan, Kaohsiung and Pindung Airports has increased rapidly due to the congested ground transport. These five airports are located in the west corridor of Taiwan, where most of the population is concentrated. Not surprisingly, these west corridor routes have become the most popular in the domestic market. The average annual growth rate of passenger traffic at these five airports was more than 20% from 1986 to 1996 (see Table 4.6).

Hualien and Taidung are located in eastern Taiwan. As there is no motorway in the east corridor, railway and air became the main transport modes for these two cities. The average annual growth rate of passenger traffic at these two airports was more than 10% from 1986 to 1996.

After the Kinmen route was deregulated, most tourists changed their destinations from Makung to Kinmen. As a consequence, traffic at Kinmen Airport has increased sharply from 1993, with an average annual growth rate of more than 45% from 1991 to 1996. With such a rapid increase in traffic the new passenger terminal built in 1991 is now too small.

#### **4.5 Air Transport Forecast**

According to the IATA Air Transport Forecast of 1997 (see Table 4.7), total domestic passenger traffic in Taiwan grew by 26% per annum on average between 1990 and 1995. The strong growth experienced in the last five years in domestic travel was the result of the development of services by several regional carriers following liberalization. The growth in international traffic was much more moderate, with an 8.7% annual rate experienced between 1990 and 1995 (see Table 4.7).

IATA anticipated that domestic passenger traffic would grow faster than international traffic between 1995 and 2000. While domestic passenger traffic is expected to grow by 12.7% per annum between 1995 and 2000, international scheduled passenger traffic to and from Taiwan should grow by 10.9% per annum between 1995 and 2000 and 7.1% per annum thereafter.

### **5. Recent Air Transport Developments in Taiwan**

#### **5.1 APROC Plan**

The Asia-Pacific Regional Operations Center Plan (APROC) is the key to Taiwan's economic future. Whether Taiwan can respond to change, break through bottlenecks and occupy a significant place in the global economy of the 21<sup>st</sup> century all largely depend on this plan. One of the important APROC aims is the establishment of the Air Transport Centre, including

express air-cargo transit hub and air-passenger transit hub.

### **5.1.1 Express Air-Cargo Transit Hub**

A special area for express cargo operations will be planned and set up in the cargo terminal at CKS international airport. International express-cargo operators will be allocated their own exclusive operating areas within the airport. They will be permitted to install and operate their own high-efficiency equipment. A policy of liberalizing commercial air-cargo operations will be carried out. The ground services company at CKS international airport will be privatized without delay and ground handling operations will be opened up to a second operator.

The second phase of the cargo-terminal extension project at CKS international airport will be completed, a special zone for express cargo will be created and operating capacity will be expanded.

Development of the airport as an international express cargo transport hub will be accompanied by the full integration of storage, carriage, information technology, manufacturing and other related activities.

### **5.1.2 Air-Passenger Transit Hub**

In the short term, to make Taiwan more attractive to transit passengers:

- i). The first phase of the plan to extend and improve the passenger terminal at CKS international airport will be carried out. The space for resting and shopping will be expanded and the quality of service will be raised.
- ii). The issuance of visas on arrival and the privilege of visa-free entry will be extended and custom clearance will be made more rapid and efficient, so as to render it more convenient for passengers to stop over in Taiwan.

In the mid to long term, to build up the physical infrastructure and make every effort to expand and develop passenger transit operations:

- i). The second phase of the CKS international airport terminal extension and development plan will be vigorously pressed ahead with. Commercial areas and rest facilities will be greatly increased.
- ii). The airport's ground transport links will be improved. Long-distance bus services to and from the airport will be opened up to a second operator. A rapid transit network will be built to connect the airport to Taipei. Air routes will be opened for connecting flights to central, southern and eastern Taiwan.

To strength management and organization:

- i). In the short-term, corporate-management practices will be introduced. Changes will be made to the organization and functions of the Civil Aeronautics Administration to strengthen its operational efficiency.
- ii). The second phase of the terminal project will be put under private-sector management.
- iii). The airport's commercial operations, such as hotel accommodation, shops, restaurants.

cafeterias, parking lots and the maintenance of the terminal facilities, will be assigned to private-sector management.

## **5.2 Open Skies Agreement with the U.S.**

In March 1997, Taiwan signed an Open Skies 'agreement with the U.S., Taiwan being the 16th country to sign such an agreement with U.S.

After the signing of the Open Skies 'agreement with the U.S., the two main international airlines, EVA Airways and China Airlines, entered into alliances with Continental Airlines and American Airlines respectively. EVA Airways began its codeshare agreement with Continental Airlines in March 1998, with Continental Airlines codesharing on EVA Airways' flights from Los Angeles, San Francisco, Seattle, Newark and Honolulu to Taipei. In turn, EVA Airways will codeshare on Continental's flights throughout the U.S. By linking flight schedules, the two carriers will greatly reduce flight connection times between the U.S. and Asia. The agreement also enables Continental and EVA to offer reciprocal frequent flier programs, shared airport lounges and through check-in to final destinations.

China Airlines began its codeshare agreement with American Airlines in December 1997, with China Airlines codesharing on American Airlines' services from Los Angeles and San Francisco to Dallas, Chicago, Miami, New York and Washington D.C. In turn, American Airlines will codeshare on China Airlines' flights to Taiwan. The agreement also enables China Airlines and American Airlines to offer reciprocal frequent flier programs, shared airport lounges and through check-in to final destinations.

## **5.3 Domestic Airline Alliances**

Airline Alliances have become popular in the domestic market of Taiwan in recent years. They first appeared in the 1980s when China Airlines acquired 19% of FarEastern Air Transport's shares. With the benefit of alliances, airlines provide passengers with more flexible choices by enabling them to take alliance partner airlines' flights using the same tickets.

Recent alliance activities have occurred since the purchase of 24% of the shares of Great China Airlines and 43% of the shares of Makung Airlines by EVA Airways in 1995. By purchasing shares, EVA Airways has built up close alliance relationships with Great China Airlines and Makung Airlines, which have benefited from receiving EVA's support on crew training, maintenance, service, ticketing image. EVA benefited by rapidly expanding its domestic network, acquiring a number of feeders for its international routes, increasing its domestic market share and acquiring precious slots at some congested airports. All airlines benefited from reduced operating costs through sharing facilities and by ordering the same type of aircraft. Great China, Makung and EVA together have ordered the MD90, getting a much better price in the process. EVA Airways went on to expand its alliance activity to include Taiwan Airlines, purchasing 29.74% of its shares in 1996.

China Airlines followed the trend by forming an alliance with TransAsia Airways on the



Taipei-Kaohsiung route in 1995. China Airlines further expanded its alliance activity by purchasing 33% of the shares of Formosa Airlines in June 1996.

With the alliance benefit, the most competitive Taipei-Kaohsiung route has become closer to an oligopoly market of three major groups instead of the original competitive market formed by seven operators. China Airlines, TransAsia Airways and Formosa Airlines form one alliance, which took 41% market share in 1995. EVA, UNI, Great China and Taiwan Airlines form another alliance, taking 21% market share in 1995. FarEastern Air Transport, the dominant carrier in the market, continues to operate independently and took 38% market share in 1995. U-Land Airlines was the only small airline which did not join any alliance and took less than 0.2% market share in 1995.

## **6. The Current and Future Environment in the Asia-Pacific Region**

### **6.1 Rank of Major Asian Airports**

#### **6.1.1 Air Passengers**

In 1996, CKS International Airport ranked 8th of the selected major ten airports in Asia and 50th in ACI world airport statistics in terms of passenger traffic. If only international passengers traffic is included, however, CKS International Airport was ranked 6th of the selected ten major airports in Asia (see Table 6.1).

#### **6.1.2 Air Cargo**

In 1996, CKS International Airport's air cargo traffic ranked 5th of the selected major ten airports in Asia and 18th in ACI airport ranking. Developing CKS International Airport into an Air Cargo Transit Hub is therefore easier to accomplish than the plan to develop it into an Air Passenger Transit Hub (see Table 6.2).

### **6.2 Top Ten Asia-Pacific Domestic City-Pairs**

The number of scheduled seats available on the Taipei-Kaohsiung route in 1996 was 8,525,804, making it the busiest domestic city-pair in the Asia-Pacific region (see Figure 6-1).

### **6.3 Air Transport Forecast for the Asia-Pacific Region**

Taiwan's total air passenger average annual growth rate was 15.4% between 1985-1995, ranking it 3rd of the major Asia-Pacific countries. According to IATA's air transport forecast of 1997, Taiwan's domestic passengers will reach 104.1 million in 2010 and its international passengers 52.8 million. Total air passenger average annual growth rate is estimated to be 8.8% over the period 1995-2010 (see Table 6.3).

### **6.4 Composition of Asia-Pacific Region Traffic to and from Taiwan**

Figure 6-2 shows the past and future composition of Asia-Pacific traffic to and from Taiwan. It can be seen clearly that Northeast Asia will remain the most important region for traffic to and from Taiwan, although its share will decline to 49% in 2010, compared to 56% in 1995 and

80% in 1985.

Traffic between Taiwan and the Americas achieved particularly high rates of growth in the recent past, with a 21% annual average rate achieved between 1985 and 1995. However, Asia-Pacific was by far the most important world region for international traffic to and from Taiwan, accounting for 87% of total international passengers in 1995.

### **6.5 International Air Traffic to and from Taiwan**

In 1985, Japan was the most important country for international traffic to and from Taiwan, followed by Hong Kong. But in 1995, Hong Kong became the most important market for international traffic to and from Taiwan. This occurred because there is no direct service between Taiwan and China (see Figure 6-3).

According to the IATA air traffic forecast of 1997, the assumed introduction of direct scheduled services between Taiwan and China in 1998 will make the Taiwan-China route area become the second most important route for Taiwan in 2010 after Hong Kong.

### **6.6 Top Ten Asia-Pacific Countries in terms of Domestic Passengers**

In 1985, Japan was by far the most important Asia-Pacific domestic travel market, while Taiwan was ranked fifth. By 1995, Japan remained the most important Asia-Pacific domestic travel market, but domestic passenger traffic in China and Taiwan had grown rapidly and ranked second and third respectively. According to the IATA air transport forecast of 1997, by 2010, China will be the major Asia-Pacific domestic travel market, followed by Japan and Taiwan (see Figure 6-4).

## **7. Conclusion**

The domestic air transport industry in Taiwan has experienced a growing trend since 1971 due to the changed economic structure and the worsening quality of surface transport. In 1987, the Ministry of Transportation and Communication (MOTC) proclaimed the 'open sky' policy for the domestic air transport industry. The policy provided a looser control on entry into the industry and of entry into new or existing routes. As a result, the demand for domestic air transport grew rapidly with an average annual growth rate of 18.35% between 1987 and 1997.

Over the past ten years, domestic airlines have increased from four in 1987 to nine in 1997, destinations served have increased from 13 to 16, routes operated have risen from 20 to 41, the total number of flights provided has increased from 76,580 to 286,170 and the total number of seats offered has increased from 4.2 million to 28 million.

In 1987, 95% of the routes operated were served by one or two carriers, but by 1996, the routes served by only one carrier had declined to 23% of the total number of routes served, whilst the routes served by four or more carriers had increased to 20%. It is clear that the operation of the air transport industry before deregulation was either monopolistic or duopolistic. Since

deregulation however, the market is much more competitive. The increased competition in the market may be explained by the larger number of airlines.

CKS International Airport is the most important international airport in Taiwan, handling 107,822 aircraft movements, 14 million international passengers and one million tons of international cargo in 1997. Its air passenger and air cargo traffic ranked 8th and 5th respectively of the selected major ten airports in Asia and 50th and 18th respectively in ACI world airport rankings in 1996.

Taipei Sung Shan Airport is a hub airport and is the busiest for domestic routes, serving more than 15 million passengers in 1996. The Taipei-Kaohsiung route is the busiest domestic city-pair in the Asia-Pacific region.

The Asia-Pacific Regional Operations Center Plan (APROC) is the key to Taiwan's economic future. One of the important APROC aims is the establishment of the Air Transport Centre, which will include an express air-cargo transit hub and an air-passenger transit hub. A special area for express cargo operations will be planned and set up in the cargo terminal at CKS international airport.

In March 1997, Taiwan signed an Open Skies' agreement with the U.S., Taiwan being the 16th country to sign such an agreement with the U.S. After the signing of the Open Skies' agreement, the two main international airlines, EVA Airways and China Airlines, entered into alliances with Continental Airlines and American Airlines respectively.

Airline Alliances have become popular in the domestic market of Taiwan in recent years since the purchase of 24% of the shares of Great China Airlines and 43% of the shares of Makung Airlines by EVA Airways in 1995. China Airlines followed the trend by purchasing 33% of the shares of Formosa Airlines in June 1996. With the benefit of alliances, airlines provide passengers with more flexible choices by allowing them to take alliance partner airlines' flights using the same tickets.

Taiwan's total air passenger average annual growth rate was 15.4% between 1985-1995, ranking it 3rd of the major Asia-Pacific countries. According to the IATA Air Transport Forecast of 1997, Taiwan's domestic passengers will reach 104.1 million in 2010 and its international passengers 52.8 million. Total air passenger average annual growth rate is estimated to be 8.8% over the period 1995-2010.

Northeast Asia will remain the most important region for traffic to and from Taiwan, although its share will decline to 49% in 2010, against 56% in 1995 and 80% in 1985. In 1985, Japan was the most important country for international traffic to and from Taiwan, followed by Hong Kong. But in 1995, Hong Kong had become the most important country for international traffic to and from Taiwan. According to IATA's assumed introduction of direct scheduled services between Taiwan and China in 1998, the Taiwan-China market will become the second most important route for Taiwan in 2010 after Hong Kong.

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Table 2.1 Categorization of Taiwan Airports Operating International and Domestic Services

Function	Characteristic	Airports	Number
International Airports	Civil only	CKS International, Kaohsiung International	2
Domestic Airport	Military and Civil Aviation	Taipei, Hsinchu, Taichung, Chiayi, Tainan, Pingtung, Hualien, Taidung, Makung, Kinmen, Matzu	11
	Civil only	Green Island, Orchid, Wangan, Chimeiuyu	4

Table 2.2 The Fleets of Taiwan's Scheduled Airlines (1995)

Airline	Aircraft	Average Seating Capacity	Fleet Size	Total Fleet Size	Operating Routes
China Airlines	MD-11	275	4	40	International and Domestic
	A 300	254	12		
	A 320	150	2		
	B 737	117	3		
	B 747	360	19		
Madarin Airways	B 747-409	411	1	1	International
EVA Airways	B 767-300ER	238	9	25	International and Domestic
	B 767-200	212	4		
	B 747-400	386	6		
	MD-11	275	6		
TransAsia Airways	ATR-42	50	3	23	International and Domestic
	ATR-72	74	12		
	A 320-231	162	6		
	A 321-131	194	2		
Far East Air Transport	B 737	120	4	15	International and Domestic
	B 757	210	2		
	MD-82	154	8		
	MD-83	165	1		
Great China Airlines	DHC-8-102	39	2	14	Domestic
	DHC-8-311	56	12		
UNI Airways	HS-748	54	2	8	Domestic and International Charter
	BAe-146	112	5		
	B 757	210	1		
Formosa Airlines	SAAB-340	36	9	26	Domestic
	Fokker-50	56	4		
	Fokker-100	109	1		
	Dornier-228	19	7		
	BN-Islander	16	2		
	UH-12E Helicopter	2/1	3		
Taiwan Airlines	BN-2A	9	4	5	Domestic
	Dornier-228	19	1		
U-Land Airlines	MD-82	154	2	3	Domestic and International Charter
	SHORTS 360	89	1		

Source: CAA, MOTC, 1996.

Table 2.3 Supply Changes in the Domestic Airline Market

Year	No. of Airlines	Destinations Served	Routes Operated	Frequencies Operated	Seats Provided
1987	4	13	20	76,580	4,199,591
1988	5	13	21	80,266	4,812,844
1989	7	13	22	107,492	5,699,800
1990	8	13	23	110,163	5,947,741
1991	8	13	24	132,782	7,862,187
1992	8	13	25	148,051	9,731,694
1993	8	14	27	176,815	13,275,809
1994	9	14	29	215,663	16,468,880
1995	9	16	33	237,458	22,022,033
1996	9	16	35	284,749	27,027,765
1997	9	16	41	286,170	27,980,000

Source: CAA, MOTC, 1998.

Table 3.1 Changes in Market Share of Domestic Transport Modes (%)

Year	Highway	Rail	Air
1980	93.50	6.36	0.14
1981	93.70	6.16	0.13
1982	93.73	6.14	0.13
1983	93.73	6.14	0.13
1984	93.98	5.88	0.14
1985	94.03	5.83	0.13
1986	93.79	6.08	0.13
1987	93.43	6.40	0.16
1988	93.19	6.62	0.19
1989	92.89	6.86	0.25
1990	92.20	7.53	0.27
1991	91.99	7.70	0.32
1992	91.12	8.47	0.41
1993	90.56	8.93	0.51
1994	89.61	9.70	0.68
1995	88.56	10.51	0.93
1996	87.53	11.23	1.23

Source: Transport Data Analysis, IOT, MOTC, 1987-1997.

Table 3.2 Competition in City-Pair Routes

Year	One Carrier		Two Carriers		Three Carriers		Four or More Carriers		Total Routes
	Routes	%	Routes	%	Routes	%	Routes	%	
1987	8	40.00	11	55.00	0	0.00	1	5.00	20
1988	8	38.10	9	42.86	1	4.76	3	14.29	21
1989	8	36.36	9	40.91	2	9.09	3	13.64	22
1990	8	34.78	9	39.13	3	13.04	3	13.04	23
1991	9	37.50	9	37.50	3	12.50	3	12.50	24
1992	8	32.00	12	48.00	1	4.00	4	16.00	25
1993	10	37.04	11	40.74	3	11.11	3	11.11	27
1994	9	31.03	11	37.93	6	20.69	3	10.34	29
1995	11	33.33	12	36.36	6	18.18	4	12.12	33
1996	8	22.86	17	48.57	3	8.57	7	20.00	35
1997	13	31.71	16	39.02	5	12.20	7	17.07	41

Source: CAA, MOTC, 1998.

Table 3.3 Changes in Market Shares (%) of Scheduled Airlines

Year	China Airlines	FarEastern Air Transport	TransAsia Airways	Great China Airlines	Formosa Airlines	Taiwan Airlines	Makung Airlines (UNI)	China Asia Airlines (U-Land)	EVA Airways
1986	31.60	57.37	-	-	6.53	4.50	-	-	-
1987	36.09	52.41	-	-	7.41	4.09	-	-	-
1988	37.07	51.53	1.00	-	7.64	2.76	-	-	-
1989	29.06	43.22	6.66	3.28	10.52	2.98	4.28	-	-
1990	20.13	44.52	11.01	6.06	10.06	2.91	5.18	0.13	-
1991	16.32	37.74	16.00	8.16	8.04	2.18	11.58	0.06	-
1992	11.04	43.08	18.69	8.74	6.95	1.48	9.82	0.18	-
1993	8.51	43.40	21.97	9.30	6.76	0.91	9.15	0.01	-
1994	6.48	40.17	26.26	9.60	7.98	0.63	8.53	0.06	0.29
1995	4.59	37.96	27.45	10.10	8.63	0.68	7.47	0.15	2.96
1996	4.30	30.39	25.08	9.87	10.75	0.85	9.95	4.72	4.08
1997	4.85	29.04	21.64	10.89	11.51	1.22	11.48	6.11	3.26

Source: CAA, MOTC, 1998.

Table 3.4 Changes in Market Share (%) by Route

Route	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Taipei-Kaohsiung	32.01	32.76	33.54	34.63	37.07	39.61	39.07	37.52	37.18	40.94
Taipei-Tainan	6.24	5.99	6.3	7.38	9.05	10.19	11.4	12.02	11.49	11.84
Taipei-Hualien	13.54	13.22	11.84	11.34	9.27	8.18	7.17	7.05	6.86	6.39
Kaohsiung-Makung	14.15	15.11	13.64	12.77	11.15	9.29	7.99	6.50	5.80	4.93
Taipei-Taidung	4.14	4.26	5.05	5.60	5.20	5.30	5.23	5.30	5.45	4.89
Taipei-Kinmen	0.52	2.09	2.32	2.64	2.66	3.25	5.12	5.71	4.95	3.85
Taipei-Makung	10.54	10.46	10.72	10.36	9.88	7.86	6.67	5.23	4.50	3.68
Kaohsiung-Hualien	3.53	3.53	3.18	3.10	2.66	2.39	1.84	1.73	1.85	1.86
Taichung-Makung	2.19	2.29	2.24	2.24	2.35	2.45	2.06	1.79	1.60	1.41
Tainan-Makung	2.16	1.92	2.46	2.32	2.31	2.01	1.74	1.52	1.30	1.00

Table 3.5 Changes in Air Fares (NT Dollars) of Inland Routes

Route	1990	1993	1996	Increase % from 1990-1993	Increase % from 1993-1995
Taipei-Kaohsiung	1209	1323	1409	9.43	6.50
Taipei-Tainan	1110	1239	1325	11.62	6.94
Taipei-Chiayi	1050	1181	1272	12.48	7.71
Taipei-Taichung	840	945	1023	12.50	8.25
Taipei-Hualien	919	1028	1111	11.86	8.07
Kaohsiung-Hualien	1335	1428	1511	6.97	5.81
Taichung-Hualien	1820	1900	1975	4.40	3.95
Taipei-Taidung	1226	1323	1407	7.91	6.35
Kaohsiung-Taidung	1004	1130	1214	12.55	7.43
Taichung-Taidung	1960	1960	2036	0.00	3.88

Table 3.6 Changes in Air Fares (NT Dollars) of Off-shore Island Routes

Route	1990	1993	1996	Increase % from 1990-1993	Increase % from 1993-1995
Taipei-Makung	1044	1164	1252	11.49	7.56
Kaohsiung-Makung	736	821	909	11.55	10.72
Tainan-Makung	699	779	867	11.44	11.30
Taichung-Makung	1044	1051	1091	0.70	3.81
Chiayi-Makung	721	804	897	11.51	11.57
Taipei-Kinmen	1544	1544	1629	0.00	5.51
Kaohsiung-Kinmen	1234	1376	1461	11.51	6.18
Taidung-Orchid	990	1104	1154	11.52	4.53
Taidung-Green Island	495	552	602	11.52	9.06
Kaohsiung-Orchid	1395	1555	1607	11.47	3.34
Kaohsiung-Chimeiye	1170	1305	1358	11.54	4.06
Chimeiye-Makung	580	647	701	11.55	8.35
Kaohsiung-Wangan	1195	1332	1385	11.46	3.98



Table 4.1 Major Facilities of Taiwan's International Airports

Facilities			CKS International Airport	Kaohsiung International Airport
Runway	Main Runway	Number	2	1
		Length x Width (m)	3660 x 60 3350 x 60	3150 x 60
	Aided Runway	Number	1	1
		Length x Width (m)	2752 x 45	3050 x 45
Passenger Terminal	Total Floor Area (m <sup>2</sup> )		163,900	68,200
	Stands	In-contact	B747 x 10 Wide Body x12	B747 x 4 Wide Body x 8
		Remote	B747 x 8	-
	Parking Slots	Bus	55	30
		Car	2,098	1,140
		Taxi	150	238
Cargo Terminal	Total Floor Area (m <sup>2</sup> )		94,180	50,900
	Stands		B747 x 4 Wide Body x8	B747 x 4
	Parking Slots	Truck	115	36
		Car	520	215

Source: IOT, MOTC, 1998.

Table 4.2 Airport Traffic Data (1997)

Airport	Aircraft Movements		Passengers		Cargo (tons)	
	Domestic	International	Domestic	International	Domestic	International
CKS	1,096	107,822	21,560	14,163,294	420	1,099,745
Kaohsiung	114,711	27,908	9,223,316	2,905,388	21,057	104,184
Taipei	187,998	-	15,394,038	-	39,596	-
Hualien	28,300	-	1,855,722	-	3,521	-
Taidung	39,870	-	1,398,643	-	3,691	-
Makung	51,044	-	2,124,330	-	13,692	-
Taichung	50,402	-	1,878,247	-	4,837	-
Tainan	26,790	-	2,496,419	-	4,397	-
Chiayi	22,771	-	1,043,695	-	2,134	-
Chimei-yu	5,583	-	43,861	-	424	-
Wangan	1,217	-	8,714	-	113	-
Orchid	5,433	-	66,719	-	326	-
Green Island	13,684	-	162,394	-	392	-
Kinmen	19,320	-	1,397,638	-	7,709	-
Matzu	7,141	-	103,008	-	821	-
Pingtung	4,755	-	181,255	-	521	-
Total	580,115	135,730	37,399,559	17,068,682	103,651	1,203,929

Source: CAA, MOTC, 1998.

Table 4.3 Changes in Aircraft Movements

Year	CKS International Airport		Kaohsiung International Airport		Total
	Movements	Percentage	Movements	Percentage	Movements
1990	56,537	93%	4,154	7%	60,691
1991	62,080	91%	6,101	9%	68,181
1992	68,982	89%	8,560	11%	77,542
1993	74,451	85%	13,479	15%	87,930
1994	83,409	83%	16,974	17%	100,383
1995	92,195	82%	19,599	18%	111,794
1996	101,371	82%	22,560	18%	123,931
1997	108,918	80%	26,812	20%	135,730
Annual Ave. Growth Rate	9.82%		30.53%		12.19%

Table 4.4 Changes in International Passenger Traffic

Year	CKS International Airport		Kaohsiung International Airport		Total
	Passengers	Percentage	Passengers	Percentage	Passengers
1990	8,929,218	92%	750,701	8%	9,679,919
1991	9,356,836	90%	1,007,462	10%	10,364,298
1992	10,827,878	89%	1,289,395	11%	12,117,273
1993	11,153,612	87%	1,733,041	13%	12,886,653
1994	11,618,574	85%	2,054,325	15%	13,672,899
1995	12,585,798	84%	2,401,781	16%	14,987,579
1996	13,585,851	84%	2,570,947	16%	16,156,798
1997	14,184,854	83%	2,905,388	17%	17,090,242
Annual Ave. Growth Rate	6.84%		21.33%		8.46%

Table 4.5 Changes in International Air Cargo Traffic

Year	CKS International Airport		Kaohsiung International Airport		Total
	Tons	Percentage	Tons	Percentage	Tonnage
1990	594,642.8	95%	30,788	5%	625,430.5
1991	634,389.9	95%	35,737	5%	670,127.0
1992	723,490.1	95%	39,818	5%	763,307.8
1993	742,729.4	94%	50,534	6%	793,263.5
1994	746,781.6	92%	62,672	8%	809,453.4
1995	941,411.7	92%	78,385	8%	1,019,796.6
1996	986,640.4	92%	91,402	8%	1,078,042.3
1997	1,100,165.3	91%	103,763	9%	1,203,928.7
Annual Ave. Growth Rate	9.19%		18.95%		9.81%

Table 4.6 Domestic Air Passenger Traffic by Airport (Thousands)

Airport	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Ave Growth Rate
Taipei	1,839	2,347	2,794	3,326	3,430	4,191	5,929	7,438	9,609	11,802	15,204	23.6%
Taichung	55	79	98	148	137	179	350	525	800	1,181	1,596	40.0%
Chiayi	67	71	70	67	62	93	164	288	546	755	1,002	31.6%
Tainan	260	294	313	403	450	644	884	1,198	1,565	1,830	2,356	24.7%
Kaoshiung	1,385	1,779	2,057	2,388	2,445	3,039	3,903	4,726	5,675	6,989	8,055	19.3%
Pingtung	-	-	-	-	-	-	-	-	16	224	246	292.1%
Hualien	528	598	672	709	697	703	805	878	1,095	1,343	1,595	11.7%
Taidung	290	399	364	456	472	492	613	846	885	1,102	1,173	15.0%
Orchid	-	-	-	-	-	48	93	76	79	78	63	5.6%
Green Island	-	-	-	-	-	48	108	125	148	162	131	22.2%
Makung	877	1,114	1,246	1,413	1,366	1,534	1,670	1,833	1,781	1,971	2,061	8.9%
Chimeiuyu	-	-	-	-	-	24	48	56	50	23	45	13.4%
Wanan	-	-	-	-	-	10	18	18	14	17	3	-22.4%
Matzu	-	-	-	-	-	-	-	-	62	89	90	20.5%
Kinmen	-	-	-	-	-	196	290	626	914	1,204	1,279	45.5%
Total	5,300	6,680	7,610	8,910	9,060	11,200	14,880	18,640	23,240	28,770	34,896	20.7%

Source: Transport Data Analysis, IOT, MOTC, 1987-1997.

Table 4.7 Air Traffic Forecast for the Taiwan Area

Year	Domestic Flights		International Flights		Total	
	Passengers (millions)	Growth Rate	Passengers (millions)	Growth Rate	Passengers (millions)	Growth Rate
1985	5.85	-	4.80	-	10.65	-
1990	9.04	9.1%	10.43	16.8%	19.47	12.8%
1995	28.74	26.0%	15.82	8.7%	44.56	18.0%
2000	52.20	12.7%	26.53	10.9%	78.74	12.1%
2010	104.13	7.1%	52.76	7.1%	156.89	7.1%

Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

Table 6.1 Passenger Traffic at Major Asian Airports (1996)

Rank of Asian Airports	ACI Airport Ranking	Airport	Total	International	Domestic
1	9	Seoul Kimpo	34,706,158	14,705,015	19,736,711
2	17	Kai Tak	30,212,327	29,542,500	-
3	24	Narita	25,408,779	22,665,870	794,729
4	26	Bangkok	24,992,738	16,380,434	6,530,554
5	27	Chang-I	24,514,248	23,129,802	-
6	42	Kansai	18,849,164	10,095,871	8,222,544
7	44	Beijing	16,383,225	3,909,970	12,473,255
8	50	CKS	15,613,624	13,585,851	-
9	-	Shanghai	12,344,826	*	*
10	71	Manila	11,938,454	7,297,108	4,641,346

Source: Airport International July/August 1997.

Note: Total passengers includes arriving, departing and transit.

\* The original data for Shanghai Airport was collected with total passengers and cannot be separated into international and domestic passengers.

Table 6.2 Air Cargo at Major Asian Airports (1996)

Rank. of Asian Airports	ACI Airport Ranking	Airport	Cargo (tons)
1	5	Narita	1,625,840
2	6	Kai Tak	1,590,772
3	9	Seoul Kimpo	1,361,510
4	12	Chang-I	1,190,457
5	18	CKS	796,155
6	22	Bangkok	787,539
7	-	Kansai	592,557
8	-	Manila	393,344
9	-	Beijing	390,098
10	-	Shanghai	304,977

Note: - means the airport was not shown in the statistics of ACI.

Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

Table 6.3 Asia-Pacific Region Major Countries Air Transport Forecast (Millions)

Country	1985-1995		2010		1995-2010
	Average Annual Rates of Growth	Domestic Passengers	International Passengers	Total	Average Annual Rates of Growth
China	22.9%	229.1	62.3	291.4	10.9%
Japan	7.0%	134.0	91.6	225.6	4.4%
Taiwan	15.4%	104.1	52.8	156.9	8.8%
Korea	16.7%	54.0	54.9	108.9	7.8%
Australia	6.9%	61.4	32.5	93.9	6.5%
Thailand	12.6%	22.3	49.1	71.4	8.1%
Hong Kong	11.3%	0.0	70.8	70.8	6.5%
India	4.7%	38.3	22.1	60.4	7.2%
Singapore	9.6%	0.0	56.1	56.1	6.6%
Indonesia	12.0%	22.6	28.8	51.4	8.2%
Malaysia	10.1%	13.0	33.5	46.5	6.7%
Philippines	6.0%	17.4	18.3	35.7	7.9%

Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

Figure 1-1 Changes in Taiwan's Population from 1983 to 1997

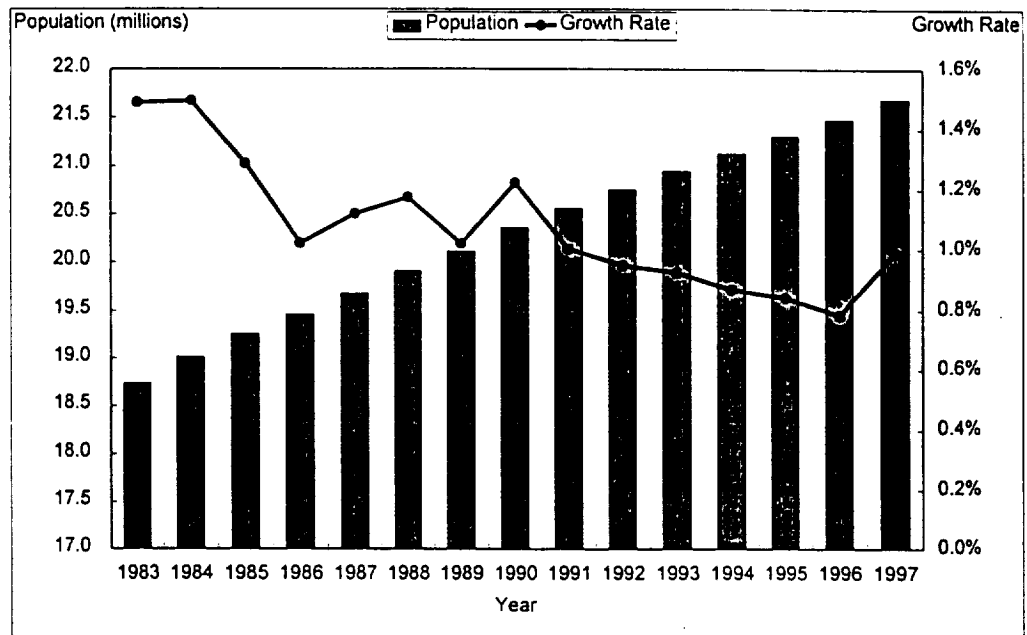


Figure 1-2 Changes in Taiwan's GDP from 1983 to 1997

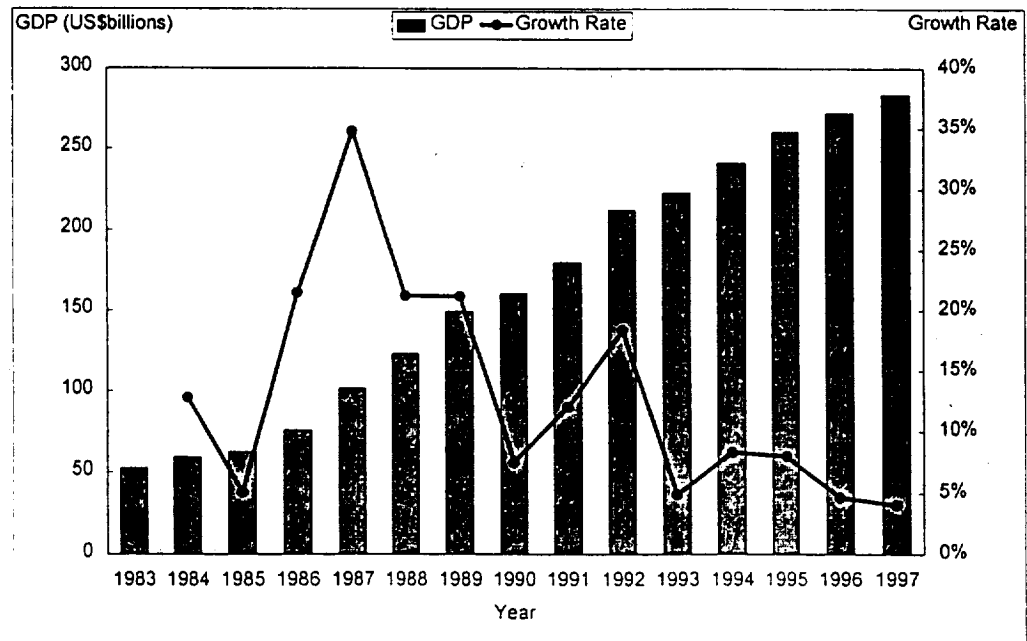


Figure 2-1 The Location of Airports and Airline Routes in the Taiwan Area

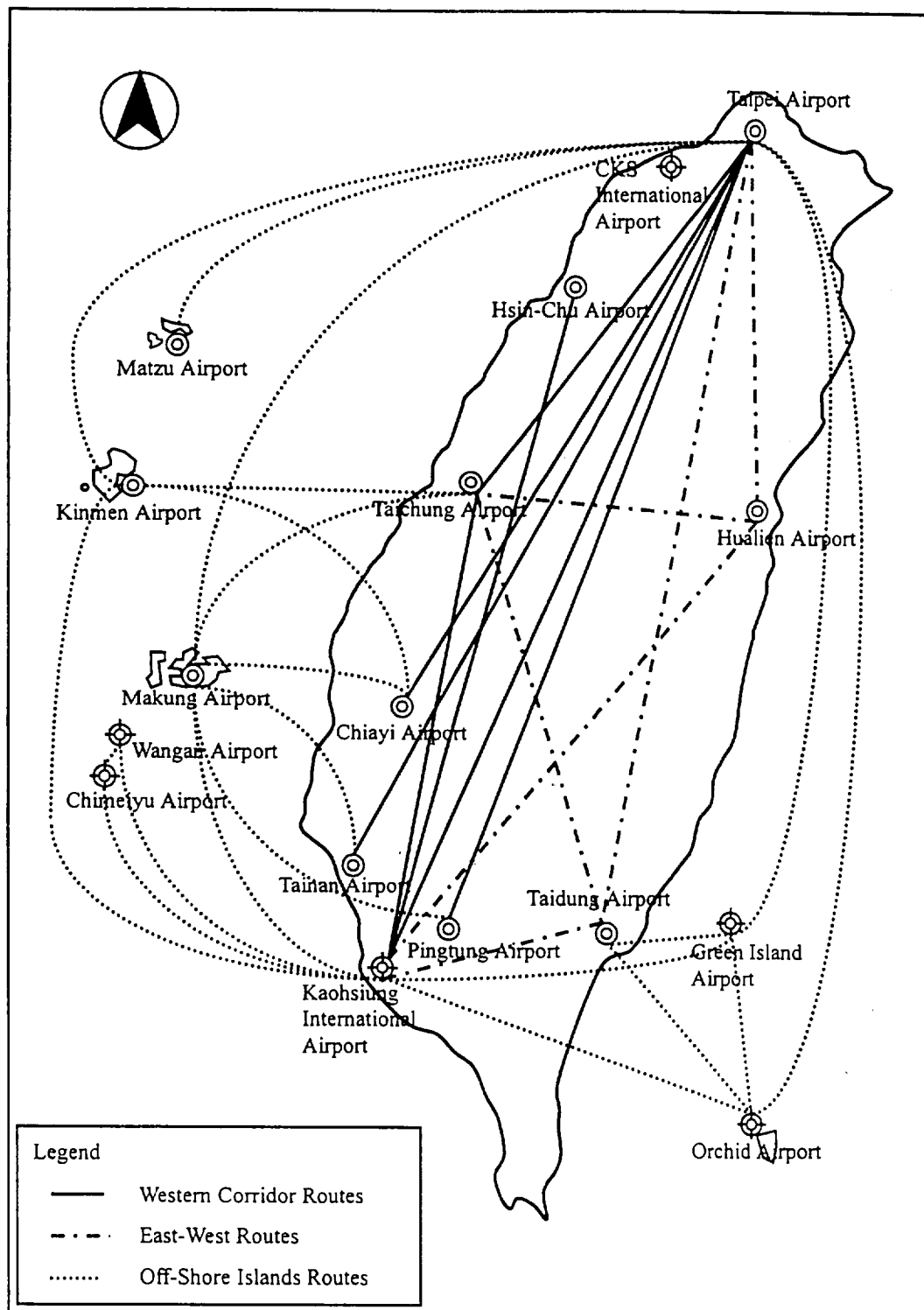


Figure 3.1 Changes in Domestic Air Transport Passenger Demand

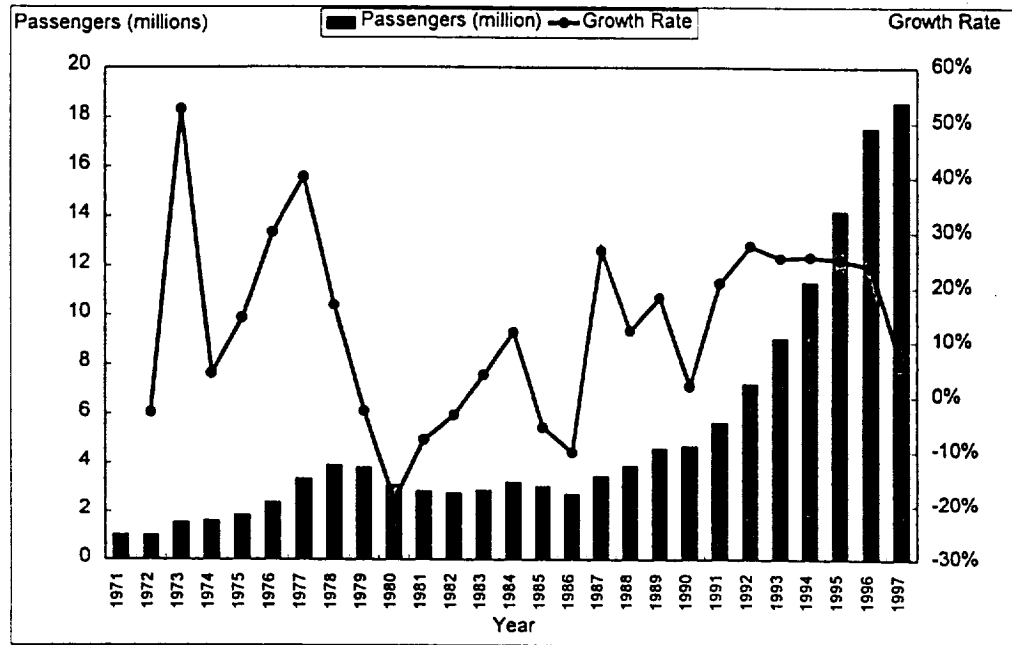


Figure 3.2 Changes in Demand for and Supply of Domestic Passenger Air Transport

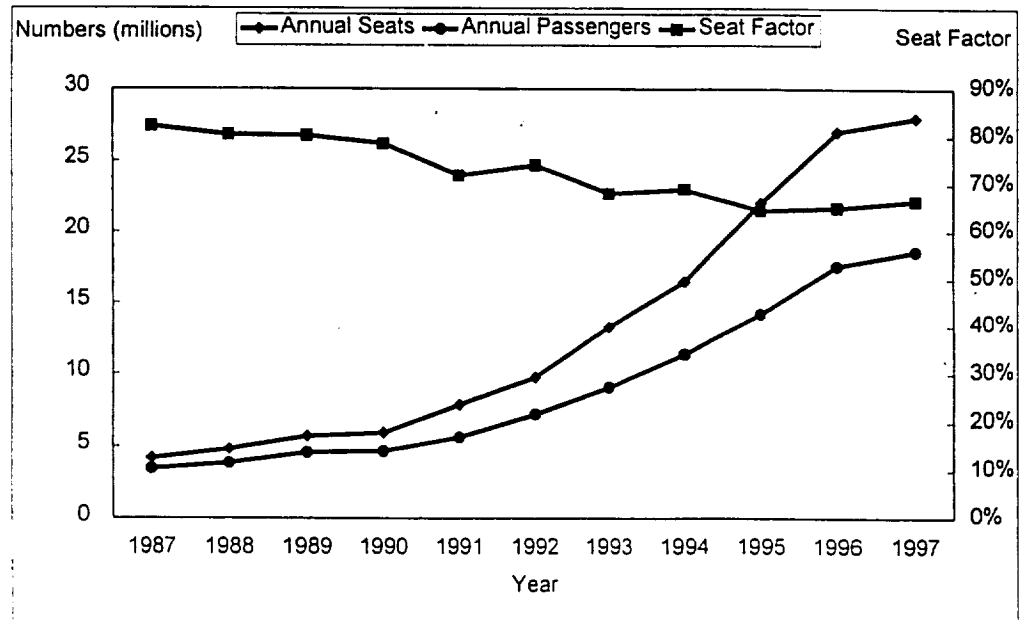
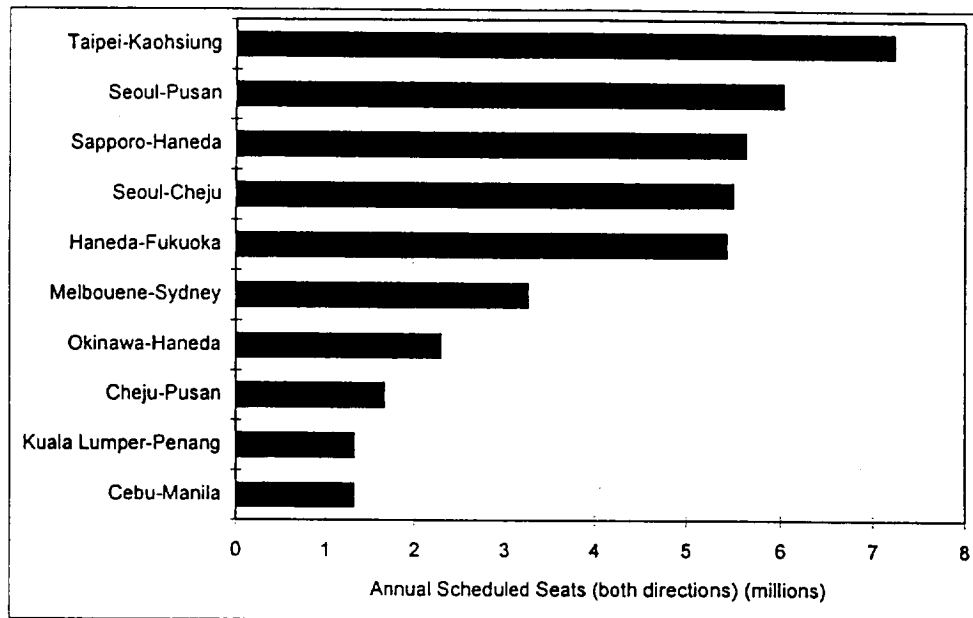


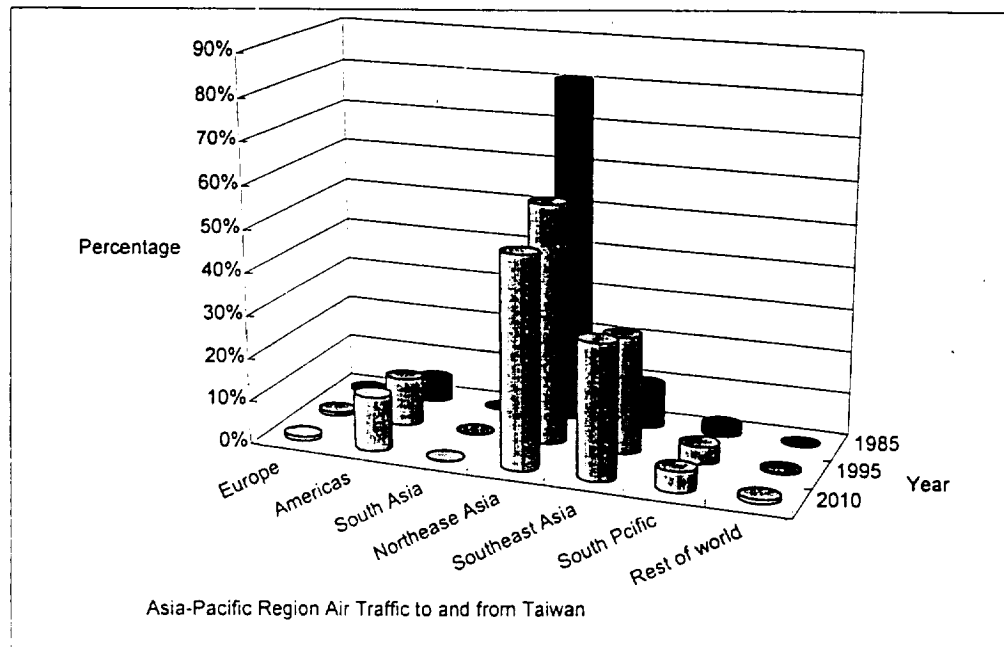


Figure 6-1 Top Ten Asia-Pacific Domestic City-Pairs in 1996



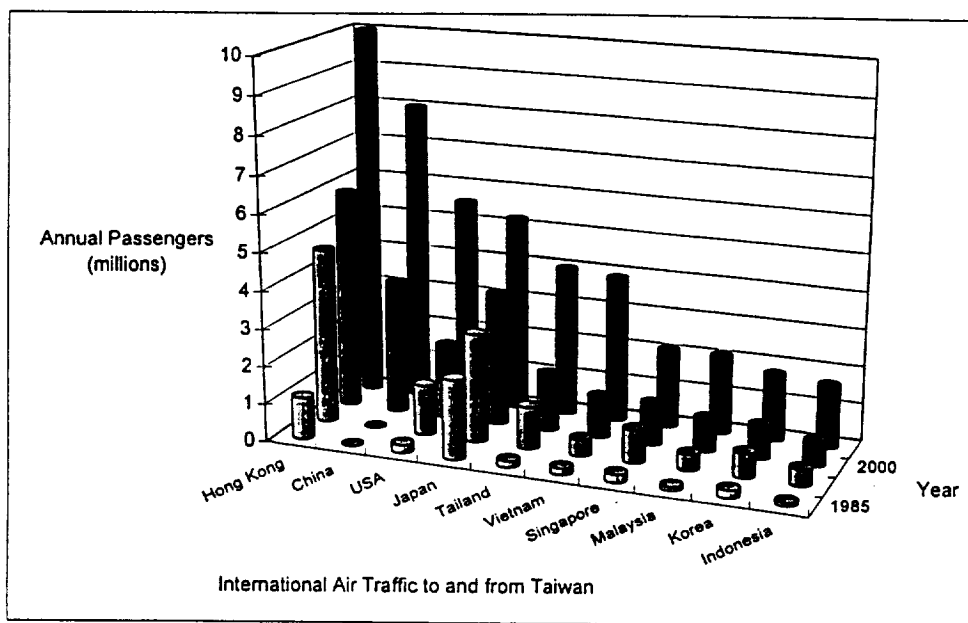
Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

Figure 6-2 Past and Future Composition of Asia-Pacific Region Traffic to and from Taiwan



Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

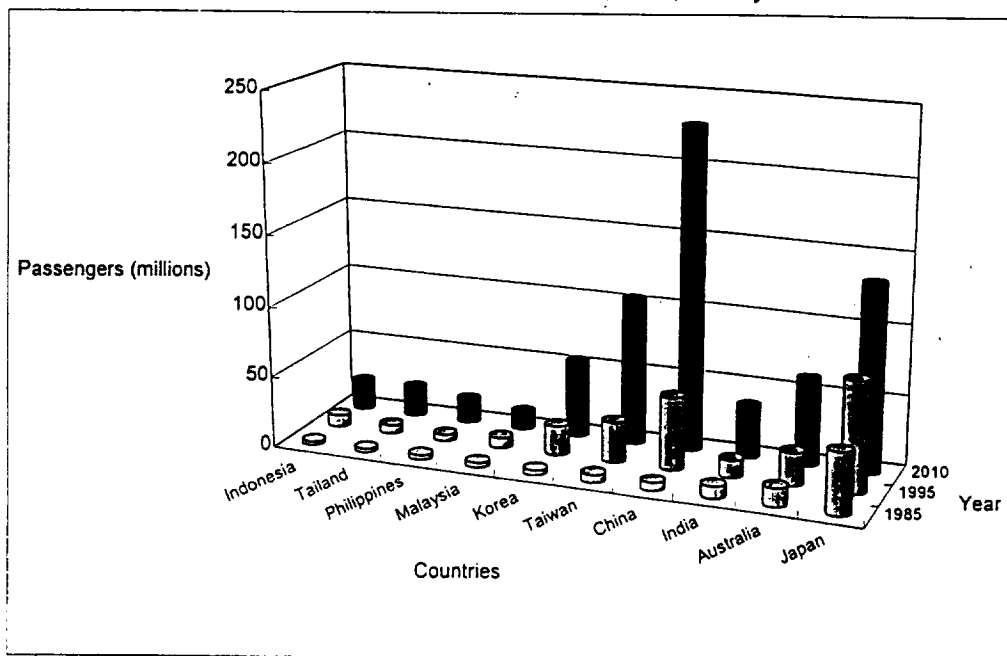
Figure 6-3 International Air Traffic to and from Taiwan



Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.

Figure 6-4 Top Ten Asia-Pacific Countries in terms of Domestic Passengers in 1985, 1995 and 2010

Source: "Asia-Pacific Air Transport Forecast 1980-2010", IATA, January 1997.



# Airport Choice & Competition – a Strategic Approach

Benedikt N. Mandel

MKmetric Gesellschaft für Systemplanung mbH,  
Durlacher Allee 49,  
76131 Karlsruhe, FRG  
email: *mandel@mkm.de*

## Abstract

After discussing some background information of the aviation sector, a strategic approach for the airport management is shown, which can be embedded in the decision making process. Two modelling issues are highlighted. The one concerns the non-linearity of consumer behaviour which touches a major principle in modelling including the airport choice and the other issue deals with competition in the aviation sector focusing on the possibility of measuring it so that a quantification is possible.

The applied system approach ensures that effects based on the synergy of air networks, the competition among air alternatives and between air and the land based modes as well as the co-operation of modes are taken into account in the simulation process. Therefor a consistent simulation instrument is available to forecast effects of supply changes on travel demand.

The selected strategic analyses shown in the last section are based on elasticities subject to the strategic simulation instrument VIA to forecast effects of supply changes on travel demand. The non-linear approach uses point as well as cross elasticities of the demand side with respect to supply characteristics.

## Keywords

Air transport, strategic simulation, strategic supply changes, airport choice, travel demand, discrete choice, consumer behaviour, non-linearity, asymmetry, threshold, Box-Cox Logit, multimodality, competition of modes, intermodality, co-operation of modes, intramodality, competition of airports or air services, elasticity of demand, trip purposes, market shares, catchment-area, location of airports, passenger charges, aircraft fees, airport pricing strategy, access / egress choice, system approach, management strategies.

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## 1. BACKGROUND

The ongoing world wide process of liberalisation and deregulation is accompanied by increasing privatisation in the air industry. Obviously this new situation has fundamental impacts and needs consideration in strategic planning. Hence, the necessity is given to know more about existing competition and - in prospective context - possibilities to assess it so that different market situations can be evaluated and incorporated into management strategies.

While airlines faced the rules of competition already for some time the airports were mostly excluded due to a number of reasons.<sup>1</sup> Airlines react to the new competitive situation with large productivity optimisation programs to cut down costs and the lease of aircrafts to enlarge the short-term financial flexibility. In parallel, they defend their markets by using marketing strategies like frequent flyer programs, lounge membership schemes or in future by the planned project 'virtual airline' as well as by establishing international alliances (code sharing, cross-share holding, franchising).

The concentration of the supply side by the alliances reduces the competition so that e.g. in Europe almost two thirds of the existing O-D's are monopoly services, one quarter of the routes is served by two carriers (which often belong to the same alliance) and only on the remaining routes there are three and more competitors. In the last case - which covers a third of the total passenger volume transported - the consumers benefited from a significant drop in price in the past.

Further competition could be expected due to further liberalisation, new entrants offering low-cost services, established 'national' airlines extending their businesses to other European areas, increasing capacity constraints and improved high speed services.

The situation at most airports is different because they are still owned by the public and with some exceptions (hubs and privatised airports) the necessity for competitive behaviour was not given. While the privatisation process is going on, subsidies are cut down and productivity has to be increased, secondary airports withdraw passengers from the major ones, capacity constraints exist at a lot of airports and huge investments are requested to solve existing problems. Furthermore airline alliances redirect passenger flows to secondary hubs due to the higher prices and / or capacity constraints at major hubs as well as based on the optimisation of the air

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<sup>1</sup> These includes restrictive bilateral air agreements, the lack of deregulation and privatisation, the procedures to define aircraft fees and passenger charges, the available capacity resources and the missing or small sensitivity of the public to environmental effects, etc.

alliance supply in total. In addition various airports offer special services on the non-aviation side.

The latter could be interpreted as airports are starting to act like private companies in a competitive market. They have to fight for customers, increase their attractiveness for passengers as well as for airlines and cope with competition at the airport itself (e.g. ground handling). Marketing and market analysis becomes more important to be able to react fast and precisely to market changes and to develop strategies for mid- and long-term investments. If the management fails (e.g. with the pricing strategy or the infrastructure investments) well established airports of today will be downgraded by the consumers and airlines to second or third league airports of tomorrow.

The European air market is facing additional policy interventions in form of new deregulations and regulations. There is international pressure to follow an open sky policy<sup>2</sup> and to cut down subsidies rigorously to allow fair competition. Further on politicians are approached by the public to internalise external costs due to increasing environmental sensitivity.

Fees or taxes on aircraft emissions and demand-based aircraft fees as well as passenger charges or quotas for air movements and noise are applied or taken into consideration. Additional interventions are expected to harmonise the market conditions with respect to airport cost structures, local landing fees and passenger charges.

Demand and supply should be the only forces in a free market but the existing access to the market conditions needs some additional rules to transform e.g. the restrictive grandfather rights on the slot allocation side into an open system where slots can be traded. The necessity to install such rules is given in the light of the capacity constraints faced by nearly any big airport and the slot blocking politics specially of home carriers at hubs, which prevent new competitors from entering the market.

New regulations are welcomed by privatised airports as opportunities to maximise their revenues by optimising resource management. Therefore peak pricing could be used to cope with capacity constraints - but one has to ensure by price caps that airports do not withdraw monopoly rents extensively and that new entrants will have a fair chance. So scarce resources at congested airports handled at market price will lead to shifts to other airports or land-based modes. In parallel, aircraft fee structures can be

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<sup>2</sup> Non-European carriers should have 'unrestricted' access to the European air market. Naturally such harmonisation issues have to be in-line with other actions, for example the assignment of a landing point to a specific airport in a bilateral agreement discriminates all other airports which are not considered.



used as instruments to meet quotas of noise and aircraft movements.<sup>3</sup>

Airlines and airports have to show great flexibility in adjusting their supply to the changing demand and regulatory framework in order to survive in the evolving market. Therefore the decisions for long- and mid-term strategies become more and more difficult and decisive as they might comprise costly investments in air-related infrastructure (including high speed railway stations at airports), market oriented pricing to handle sparse resources or to develop new markets, new services in the non-aviation sector or the extension of hub & spoke versus point-to-point air schedules.

The resulting complexity in decision-making processes in the air industry requires enhanced planning instruments to apply appropriate means from the administrative side and to adjust supply structures that will enable the carriers and airports to stand the increasing competition. The following sections will direct towards a strategic planning instrument which helps to face the complex problems stated, so that the managers can enrich their knowledge by analyses and scenarios to reduce the entrepreneurial risk in decision making. Enhanced econometric models which analyse and explain possible consumer reactions on adjusted supply figures offer the opportunity to study the interdependencies in the market structures, to anticipate future changes and to evaluate the resulting effects on both – the microeconomic and the macroeconomic level.

Being the public transport mode with the highest increase in demand during the last years an appropriate instrument for analysing air services impacts is therefore highly recommended. Unfortunately air traffic is a fairly complicated mode to handle – from a modellers point of view.

The unimodal approaches to assess changing market situations are more or less sophisticated extrapolations of the past and it turned out that they are poor predictors. Forecast processes that take additionally into account other alternatives which are accessible from a consumer's point of view will predict in a better way. Hence, multimodal approaches which incorporate inter- and intramodal as well as synergetic network effects are *per se* more sufficient to cope with real life complexity.

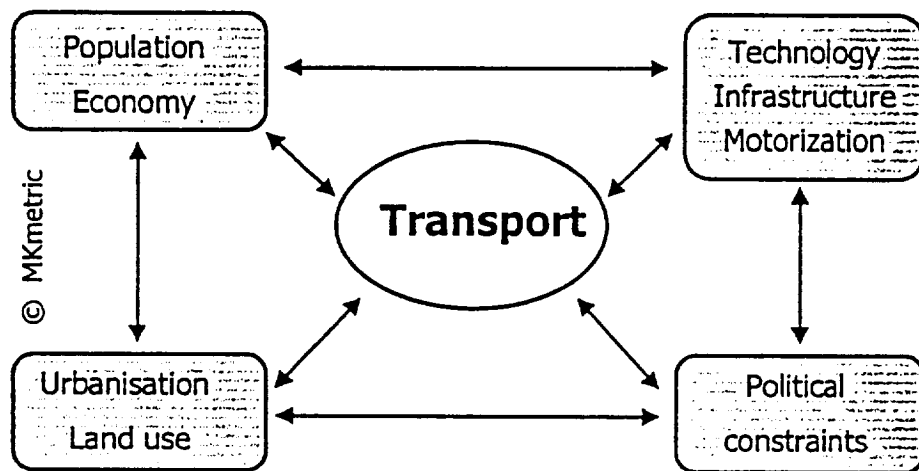
Although the approach which will be shown is much richer, within this paper it is not possible to deal with all possibilities and all problems. Therefore the obvious ones like long term forecasting based on different socio-economic, infrastructure and transport policy scenarios will stand aside. Here the focus is on the consumer side which at least decide due to their sensitivity where the business goes to. Some of the results shown in the final section will indicate that the scope of the underlying studies was much wider.

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<sup>3</sup> Modified aircraft fees could force airlines also to increase their load factors above the miracle barrier of 70 per cent.

## 2. SYSTEM APPROACH

A consequent development of this scope leads to a systemic view of transportation. It is therefore necessary to embed air transport forecasting in a framework of relevant relationships that include and take into account the whole transport market as well as demographic, economic, political, spatial and technical components. Figure 1 gives an idea of the considered determinants.

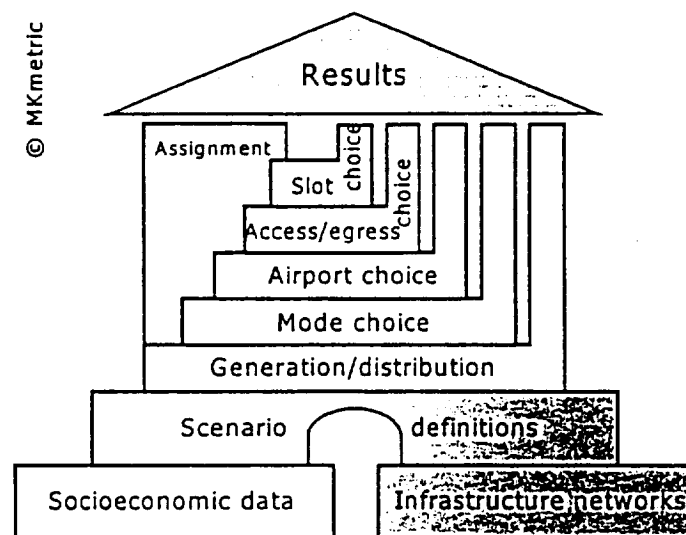


*Fig. 1. System Approach*

A modelling process based on these interrelationships explains the transport market by multimodal and multisectoral determinants. This approach ensures the consistency of the whole model system in every step of the simulation process. Considering detailed exogenous impact factors as population, economic and political circumstances, technical development and spatial structures the models always process balanced figures of all endogenous measures. Hence, no transport activity appears or disappears unexplained within the system. Changes in the system's state are substitutive or complementary and synergetic effects, as well as competition, lead to new situations concerning diversion, accessibility or attractiveness. These effects can be analysed with respect to modes (e.g. road, rail, sea, air) and/or trip purposes (e.g. business, vacation, private).

In the light of the complex problems stated above it is obvious that the airport choice model has to be embedded in some sort of model explaining total trip making by all modes and a sort of model explaining the choice of mode for a trip. It is convenient to postulate, for the sake of discussion, the existence of an aggregate generation-distribution model: this corresponds to frequent practice and the points that should be made about an ideal specification also hold when disaggregate generation-distribution specifications are used. In addition the existence of an disaggregate mode

choice model based on a logistic function, say a logit-model, has to be assumed so that the consumer elasticities with respect to the alternative modes can be identified. Some additional models are needed to face the problems of access/egress choice to the airports and slot choice to explain the consumers selection of departure time. Last but not least, assignment procedures are required to compute impedances which reflect the attractiveness of each alternative based on the infrastructure networks of all modes. Figure 2 shows the stages of air transport forecasts and the context of the different models.



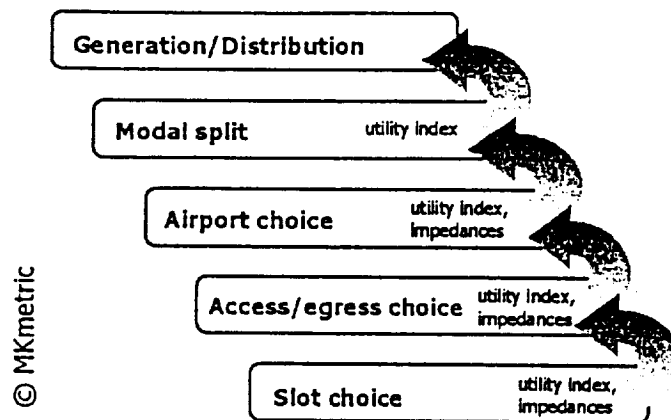
*Fig. 2. Steps of air transport forecast*

To encounter the effects from one decision level to the other, say from mode choice to generation-distribution or from airport choice to mode choice and further on to generation-distribution, one links the modelling steps by the quasi-direct format using the representative utility function of the lower level models in the upper ones as an additional explanatory variable, which we call modal utility index  $U$ .

In addition at the level of the discrete choice models the explanatory impedance variables used in the model specifications are computed considering the probabilities of the lower level model as weights. The idea of linking the models in the forecasting system is shown in Figure 3.

Applying this system approach, a consistent simulation instrument can be constructed which reflects the impacts of supply changes through all instances at any level. The effects of supply changes at an airport (e.g. a new O-D service, increasing aircraft fees, low cost tariffs) can be analysed in detail. No matter whether these are intramodal impacts, say the competition of airports about market shares as well as the competition of different levels of service (non-stop versus via connections), or multimodal impacts, say the

substitution of air traffic by inter city high-speed trains or car but also the *vice versa* case is possible due to the offers of low cost carriers, or intermodal impacts, say the co-operation of air and rail services on the access/egress side to/from the airport (like a lot of tourist companies already include in their price offers in form of rail & fly tickets). Therefore the interdependency of airport choice and travel demand can be analysed out of different point of views.



*Fig. 3. Linking the models in the forecasting system*

Instead of extending this paper by the theory of all modelling steps used in the system approach it is referred to various publications. A detailed theoretical background of the modelling steps is given by the following literature.

For the generation-distribution modelling it is referred to Gaudry-Mandel-Rothengatter 1994a, 1994b, Sen-Smith 1995 and Last 1997 and for the mode choice modelling see the publications of Mandel 1992, Mandel-Gaudry-Rothengatter 1991-1994-1997 and Mandel et al. 1997. The more general focus of discrete choice modelling you'll find in Domencich-McFadden 1975, Manski-McFadden 1981 and Ben-Akiva-Lerman 1985. The quasi-direct format is explained by Tran-Gaudry 1994. Concerning the assignment procedures there is a lot of literature therefore it is referred to a more general operations research summary by Neumann 1974 and a more transport oriented publication by Gallo-Pallottino-Florian 1984. For details of the assignment procedure used in the system approach see Last-Mandel 1997. As introduction an overview concerning all steps is given by Ortuzar-Willumsen 1990. Specific information concerning air transport is found in Doganis 1991-1992 and in several publications of the air industry and their associations like ICAO, IATA, CAC and ECAC or national ones like ADV in Germany.

After having shed a light on the global approach we are going into some modelling details which are of relevance for a sound and detailed analysis of interdependencies in the air transport market as shown e. g. in the examples of the final section.

Therefore we'll highlight the modelling aspects concerning two issues.

1. Non-linearity: to enable the models to capture existing thresholds where consumers strongly react due to changes at the supply side caused by e.g. infrastructure investments, pricing strategies or service changes.
2. Notions of competition: to explain the interdependencies of different modelling steps as well as ways to measure it so that the consumers' reaction on supply changes can be quantified and finally evaluated.

For a detailed discussion we'll refer to the papers (Mandel 1999) 'The Interdependency of Airport Choice and Travel Demand' and 'Measuring Competition in Air Transport'. In the following we'll withdraw parts of the text.

### 3. NON-LINEARITY AND THE CONSUMER'S CHOICE

On most flight journeys consumer have the opportunity to start their trip from more than just one single airport. Just in Germany there are 16 international airports and several regional airports so that often a situation appears where the consumer can choose out of a whole bunch of alternatives all serving his needs in nearly the same way. It could happen that more than four airports offer the same destination and in addition at each airport non-stop as well as via services are available. After the consumer evaluated the different opportunities, he selects only one out of the available set of alternatives. This is a classical discrete choice problem. For details see the suggested literature about mode choice and discrete choice modelling in section 2.

Here the focus is on the differences between the chosen and the standard approach and the resulting advantages. To understand the issues in an easy way we will also refer to examples taken from the field of mode choice.

#### 3.1 Properties of the linear standard model

The "classical" linear Logit model specification normally assumes (Gaudry 1992):

- (i) linearity in variables;
- (ii) the exclusion of characteristics of other alternatives  $j \in C_n$  from the representative utility of the  $i$ -th one ( $i \in C_n, i \neq j$ );
- (iii) equal "abstract" or "generic" coefficients for the network characteristics, a constraint that is not necessary but is frequently imposed.

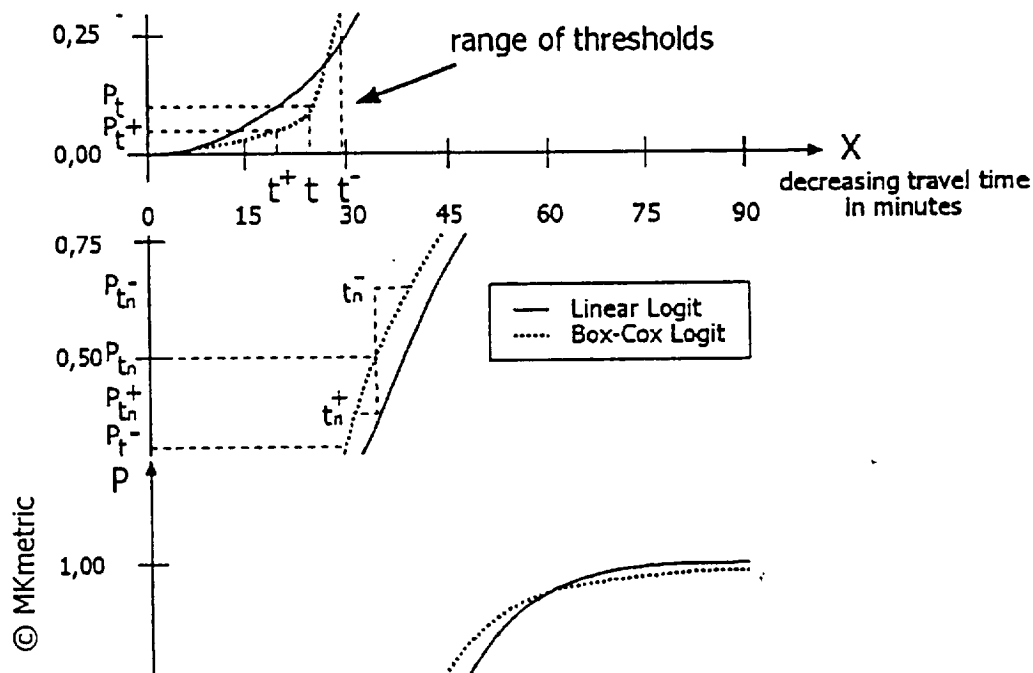
These assumptions lead to unrealistic properties. Because of (ii), the standard model implies:

- a) equal cross elasticities of demand: this means that setting up a bicycle path between two cities will draw the same percentage of travellers from the plane, car and train or in the sense of airport choice the same percentage of travellers will be drawn from all considered air services. Furthermore (iii) implies identical values of time across the alternatives: this means that representative train and plane users (mode choice) or non-stop and via flight passengers (airport choice) value time identically;
- b) the exclusion of complementarity among alternatives;
- c) that only differences in the level of characteristics matter, or that the function is not homogenous of degree 0: in consequence doubling all fares and income will change the market shares.

Because of (i) the standard model further implies that:

- d) the effect of a given difference in transport conditions is independent of the service level characteristics so that the response curve to changes in service characteristics is symmetric with respect to its inflection point (see figure 4). For instance, a 30 min rail travel time reduction has the same impact on choice probabilities for the Hamburg-Hanover (180 km) origin-destination pair as for the Hamburg-Munich (823 km) pair. Similarly increasing the air tariffs by 50 DM (US\$ 28) has the same impact on choice probabilities for the Hamburg-Frankfurt (540 km) origin-destination pair as for the Hamburg-Paris (1060 km) pair. Further on adding an amount of 20 DM (US\$ 11) to the price of travelling by plane will have the same impact as adding 20 DM to the price of travelling by train. The same holds if one directs this example to non-stop and via-alternatives in the aviation sector.

Generally speaking, symmetry, with respect to the inflection point, implies that potential asymmetry of behaviour, where consumers/travellers suddenly start to react and then change their behaviour, can not be detected;



*Fig. 4. Linear Logit versus Box-Cox Logit*

- e) coefficients for the constants and for the variables common to all alternatives are underidentified, which means that, for these variables, only differences with respect to an arbitrarily chosen reference can be identified.

We also note in passing that the logit form requires that

- f) the choice probabilities go to zero (one) when the representative utility  $V_i$  goes to  $-\infty$  ( $+\infty$ ) so that (see figure 4) one cannot model thick tails due to specification error, modeller ignorance, compulsive consumption or captivity to alternatives. The latter case includes the situation of business travellers which have to do a one day return trip and are therefore not elastic to price.

### 3.2 The Box-Cox device

To bypass most of these constraints (generally speaking, only (c) and (f) will remain), the Box-Cox transformation is used:

$$X_{kjn}^{(\lambda_{kj})} = \begin{cases} \frac{(X_{kjn}^{\lambda_{kj}} - 1)}{\lambda_{kj}} & \text{if } \lambda_{kj} \neq 0, \\ \ln X_{kjn} & \text{if } \lambda_{kj} = 0. \end{cases} \quad (1)$$

Hence, the choice model based on the logit function can be written as:

$$P(i)_n = \frac{\exp(\beta_i X_i + \sum_{k=1}^K \beta_{ki} X_{kin}^{(\lambda_{kj})})}{\sum_{j \in C_n} \exp(\beta_j X_j + \sum_{k=1}^K \beta_{kj} X_{kjn}^{(\lambda_{kj})})}, \quad (2)$$

where  $X_i = X_j = 1$  are regression constants.

If  $\lambda_{kj}$  is equal to 1 (or zero), then the variable is entered in its linear (or logarithmic) form. Since the transformation is continuous for all possible values of the  $\lambda$ -parameter, but defined only for a positive variable, it is clearly understood that in above formulas some of the  $X_{kjn}$ 's cannot be transformed: the constant, the dummies and the ordinary variables that contain negative observations. Variables that contain positive and null values can be transformed as long as a compensating dummy variable is created (Gaudry et al. 1993).

### 3.3 Visual and economic significance

Figure 4 clearly shows the difference between the linearity and non-linearity of a variable. The asymmetric curve (in respect to its inflexion point) given by Box-Cox transformation (Box et al. 1964) of the strictly positive variable  $X_i$  illustrates the error which will occur when a non-linear



variable is forced to be linear. For example, assume  $X_i$  denotes total travel time: in the linear case, the value  $X_i$  equal to 30 is associated to the probability  $P$  equal to 0.25; in the non-linear case, the probability is higher if  $\lambda < 1$  and smaller if  $\lambda > 1$ . Hence, if one forces a non-linear variable – or in equality the utility function – to be linear, this will result in an over- or underestimation of the probability related to this variable. In addition to asymmetry of the response function ( $\lambda \neq 1$ ), reaction thresholds can be identified.

The Box-Cox transformation of the strictly positive variables of the linear Logit model leads to the Box-Cox Logit model with an asymmetry of response, as shown in figure 4, because the effect of a unit change in the service will depend on the levels of the variables  $X_{kj}$  for all values of  $\lambda_{kj}$  not equal 1. This can be seen by examining the partial derivatives of the representative utility function  $V_j$  of the  $j$ -th mode. It is obvious that the effect of additional service will be smaller at higher service levels than at lower ones if  $\lambda_{kj}$  is smaller than 1. These diminishing returns mean that given absolute reductions in total travel time have more impact when total travel times are low than high: a gain in travel time of 15 minutes means less on a long trip than on a short one. The same effects appear in the case of an increase of air tariffs. Conversely, increasing returns exist if  $\lambda_{kj}$  is larger than 1.

Clearly, if one is considering very small changes in the service levels of a mode, the mathematical form used does not matter very much because one is forecasting in the immediate neighbourhood of current sample values. However, if one is considering significant changes in service levels, such as increasing aircraft fees or decreasing air tariffs by a third or reducing train travel time by one half with high-speed trains, then curvature is decisively.

### 3.4 Asymmetry

To illustrate the asymmetry of the response functions due to the inflexion point of the curve and the threshold effect mentioned before, figure 4 shows a general example of a response curve for an alternative with respect to the variable travel time while all other conditions (characteristics and alternatives) remain unchanged. On the x-axis the change in travel time is displayed (t minutes decrease in travel time on the air service alternative) and on the y-axis the change of the probability choosing this alternative is given. Hence the interdependency of airport choice and travel demand is obvious when the probability is multiplied with the total demand of the origin-destination pair which will show you the demand for the alternative.

To describe asymmetry more formally one first has to define the inflexion point of the curve. At this point the curvature changes its functional shape from convex to concave and one can compute the value of the

inflexion point  $(P_{t_n}, t_n)$  by equating to zero the second derivative of the alternative share in respect to the travel time. The response curve can be called asymmetric with respect to its reflection point if equidistant reductions and increments of travel time  $t_n$  by  $\Delta t$  [that is,  $t_n^+ = t_n - \Delta t$  and  $t_n^- = t_n + \Delta t$ ] will give different absolute values, namely  $\Delta P^+ = |P_{t_n^+} - P_{t_n}|$  and  $\Delta P^- = |P_{t_n^-} - P_{t_n}|$ ; otherwise the curve has to be called symmetric. More formally, one can define asymmetry, as in Laferrière and Gaudry (1993) in terms of the partial correlation  $\xi$  of  $P_{t_n}$  and  $(1 - P_{t_n^-})$ : this yields an indicator that is necessarily between 0 and 1.

**Threshold.** A threshold effect occurs when the travel time reaches a critical value of  $t$  beyond which any further reduction of  $t$  to  $t^+ = t - \Delta t$  provokes a more substantial growth of the mode share  $P_t$  than an equidistant increment of  $t$  to  $t^- = t + \Delta t$ , so that the absolute difference of the mode shares  $|P_t - P_{t^+}|$  is higher than  $|P_t - P_{t^-}|$ .

The word threshold implicitly involves an individual evaluation of the perception of change; hence it is up to decision maker to define his threshold by exploring the percentage of alternative share increment which he will consider as a threshold i. e. which will satisfy his opinion about a threshold. More formally a critical value  $\eta$  has to be defined so that the absolute difference of  $|P_t - P_{t^+}| = (1 + \eta) |P_t - P_{t^-}|$ . Alternatively,  $\Delta P_{t^+} = (1 + \eta) \Delta P_{t^-}$  and hence  $\eta = (\Delta P_{t^+} / \Delta P_{t^-}) - 1$ . From a visual point of view, one would intuitively expect to find the thresholds to be in the range given by the grey zone in figure 4, where a reduction of one unit would increase the probability of choosing the alternative by an additional 20% ( $\eta = 0.3$ ), so that  $\Delta P_{t^+}$  would be equal to 6 times  $\Delta P_{t^-}$ .

It is obvious that the given results in figure 4 are based on a *ceteris paribus* assumption: consequently a variation of other mode specific characteristics like frequency and travel cost would imply a change of the location of the response curve so that the threshold would have to be relocated.

It has to be mentioned that in general by interpreting the results shown in figure 4 one has to take into account that the travel time represents the time of a door to door trip. Therefore a change of the access/egress services can have an important impact on the choice of an alternative.

### 3.5 Other considerations

The purpose of the latter example is to visualise the asymmetry of the response functions, the existence of the thresholds and the impact of travel distance on consumer behaviour: it is clear that for a detailed analysis of an investment or planned action it would of course be necessary to consider in

addition the impact of travel cost, frequency, access/egress characteristics, etc.

The examination shown in figure 4 also can be done in reverse direction where one first defines the probability of choosing the mode and then computes the necessary characteristics which satisfy this condition. Different kinds of services, which are related to different actions can be represented by changes in the underlying characteristics. Implicitly there is the possibility to verify the optimal investment by relating it to the alternative specific characteristics that maximise revenue.

#### 4. COMPETITION CONCERNING AIR TRANSPORT

Before we go into some formal details we first have to state which forms of competition appear and how they can be explained.<sup>4</sup> For this purpose it is necessary to view the air market from the outside to identify all structural components of competition. The following different types of competition in the air market can be distinguished:

- competition on a single route,
- competition between networks,
- competition for infrastructure and
- competition between access/egress points.

The classical notion of competition is the rivalry between two carriers on a certain route. This kind is usually expressed in market shares kept by the competitors. The second one is measured in more aggregated market shares and means the rivalry between two and more airlines as well as those between airline alliances.

Competition for infrastructure comprises e.g. the fight for slots or ground-handling capacities. In this case limited resources on airports<sup>5</sup> are the reason for the conflict between the airlines. An often misinterpreted form of competition is that between airports, mostly owing to a special view of the air sector.

Out of a general transport point of view the supply side should be a result of the offered O-D services which include the airports and land-based access/egress modes while the demand side is given by the travellers with all their needs and priorities for a trip.

An airports' attractiveness in a condensed air market depends strongly on the capacities, the pricing structure, the land-sided accessibility and the non-aviation supply. Those factors and the carrier-related supply based on them, all together will finally attract customers, i.e. travellers and also shoppers. Hence, besides infrastructural matters the potential of customers is the major driving force for airlines to choose an airport.

The competition of airports on the cost side (passenger charges, landing fees, ground service) is already ongoing especially if one considers the non-harmonised airport costs in context of the air alliance network optimisation. Airports with 'bad' price structures, i.e. high costs for airlines (passed to the travellers through the fares), are already facing the problem that clients –

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<sup>4</sup> Naturally modellers prefer to explain the interdependencies instead of just describing observed situations because their aim is to understand the underlying structure of a system.

<sup>5</sup> Due to the fact that at least two airports are required for air routes, the constraints must not necessarily exist on both airports because slots on unconstrained airports must fit to their counterparts on the constrained ones.

travellers and airlines - look for alternatives. Therefore airlines try to combine their network synergies at 'better' airports.

While hubs are already working at this problem other airports still hesitate and focus on O-D market services. That is the reason why they estimate the influence of varied fees and charges on carrier decisions as relatively small in contrary to routing optimisation. But airlines want to satisfy the consumers needs as profitable as possible and consumers' try to obtain their optimum from the supply offered.

Neglecting such obvious dependencies and standing at the side, waiting what airlines and travellers do, is certainly an unconventional strategy which might be applicable if the airport is in a monopolistic situation e.g. due to bilateral agreements but will not suit those airport managers that view travellers as *their* clients.

They will agree to the idea that persons intending to travel from an origin to a certain destination have to be convinced to choose a route via their airport. But this route competes with those through other airports and routes that use only ground-based transport modes like (high speed) trains or private cars. Hence, airports are in a very large competition that should be considered as completely as possible in the decision-making processes.

Taking into account only the air transport system, as airlines often do, is not sufficient, when one aims at the traveller as the final driving force. But more crucial is the scope of airports when analysing the market. Neglecting neighbouring airports and also those further away as competitors falsifies any serious evaluation and in consequence any planning.

The planning and analysis instrument must therefore cover all main modes - road, rail and air for the multi-modal competition. Further, the corresponding access/egress systems have to be considered for inter-modality beside detailed representations of the air transport system itself to assess the intra-modal rivalry between airports and/or carriers.

Well-developed planning instruments based on a system approach simulates the complete supply side a travelling individual<sup>6</sup> is confronted with and from which it has to choose its path from the origin to a desired destination. Interpreting the different paths as alternatives in a choice process, competition could be measured in terms of the various probabilities to select one of the possible paths.

It is important to note that the traveller has to take a discrete decision about the alternative to be used because he can only use one alternative at each time. The choice among the set of available alternatives depends on subjective preferences and/or on the alternatives' characteristics. Neglecting individual preferences for the moment, the traveller compares the

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<sup>6</sup> We are focussing here on individuals who have just decided for a trip and do not cover those which are still in the process of decision whether to travel at all.

alternatives on the basis of their measurable characteristics like e.g. travel cost, travel time, comfort and security.

The preferences come into the decision process when the travelling person weights the 'objective' characteristics for each alternative due to its personal rating. In economics the resulting measure is referred as 'utility', i.e. the satisfaction one receives from choosing one alternative. It is obvious that consumers evaluation varies between different individuals which for example can be segmented according to their socio-economic situation (income, age, gender) or their trip purpose (business, vacation, visiting friends and relatives). More formally one can speak here of the consumer's 'elasticity' in respect to any alternative's characteristic.

The elasticity  $\eta$  just measures the ratio of the percentage variation of a dependent variable  $Y$  due to the percentage change of an independent variable  $x_k$  ( $k \in \{1, \dots, K\}$ ) given all other independent variables fixed at their observed value. As dependent variable one can use e.g. the total flow or market share -  $T_i$  or  $p_i$  - and assess the impact of passenger fare as an independent variable, keeping all other independent variables like travel time, frequency, service attributes, etc. unchanged.

The more general form for any elasticity is for the point measure is:

$$\eta(Y, x_k) = \frac{\partial Y}{\partial x_k} \frac{x_k}{Y} \quad (3)$$

As we want to focus on individual aspects of consumer behaviour we choose a disaggregate probability approach  $P(i)_n$  with underlying Logit function (see section 3). Now the direct elasticity  $\eta$  of the probability of a consumer  $n$  choosing alternative  $i$  with respect to a change in the characteristic  $x_{kin}$  is given by:

$$\eta(P(i)_n, x_{kin}) = \frac{\partial P(i)_n}{\partial x_{kin}} \frac{x_{kin}}{P(i)_n} \quad (4)$$

In addition it is interesting to know how the changes of a characteristic  $x_{kin}$  effects the probability  $P(i)_n$ . Therefore the cross elasticity of the selected probability alternative  $i$  with respect to a variable of alternative  $j$  can be computed. But in addition we want to bypass some problems caused by the properties of the classical standard Logit approach and all the interpretative problems such as equal cross elasticity's (see section 3). Equal cross elasticity's of demand imply identical 'values of time' across all alternatives: this means e.g. that non-stop and via flight passengers value time identically. Therefore a non-linear transformation to strictly positive variables is applied like stated in section 3 (see also Box-Cox (1964)).

For the interpretation of elasticities one should be aware that the values given are computed on the basis of a 1% change of the variable  $x_k$ . As the formulas (4) and (5) show, the result is a share value and therefore the interpretation always has to be put in context to the demand an alternative attracts. If the elasticity is small but the attracted demand of that alternative is high the demand effects could be bigger than in the reverse case. More formally the own elasticity is:

$$\eta = \beta_k x_k^\lambda [1 - P(i)] \quad (5)$$

where the elasticity increases with  $x_k$  and falls with the level of  $P(i)$ .

As we noted in the beginning of this section there are various areas of competition which have to be considered in total to reflect consumer behaviour. Therefore based on the shown principle idea of elasticity one can construct an equation which considers these elements. Instead of using just one discrete choice part in the formula we can add the interesting fields of airport choice, access/egress choice, time slice choice and airline choice in the following way (with simplified notion).

$$\begin{aligned} (\eta \text{ of alternative}) = & (\eta \text{ of total flow}) + (\eta \text{ of mode}) + (\eta \text{ of airport}) + \\ & (\eta \text{ of access/egress}) + (\eta \text{ of time slice}) + \\ & (\eta \text{ of airline}) \end{aligned} \quad (6)$$

This expression allows us to compute the elasticity of demand of an alternative with respect to any variable  $x_k$  considering the impacts on the following types of competitive situations:

- competition of destinations (substitution, complementarity)
- competition between the modes (air, rail and road),
- competition between co-operating modes (air-rail, air-road),
- competition between air services at airports,
- competition of access/egress modes to/from the airports,
- competition for time slices at airports and
- competition of airlines.

As already mentioned above this formula should be used for any market segment, for example business travellers tend to have a lower elasticity concerning travel expenses than for travel time and the reverse holds for holidaymakers.

Obviously to calculate such complex elasticity structures which allow detailed analyses at any point, a system approach is needed. It has to be assured that the interdependency of different models is reflected properly and therefore models have to be linked so that the results are consistent. One way of doing this is using the 'quasi-direct format' where the different

model steps are linked by the representative utility function of preceding models in the subsequent ones as additional explanatory variable. This approach can be enriched by considering the probabilities of the preceding models as weights when the explanatory impedance variables in subsequent models are computed (see Mandel (1999)).

As experts expect that the main focus of interest will be on airport competition in the coming years, we will present some strategic analyses examples in the last section based on a restricted sequence of elasticities as shown in equation (7).

$$\cdot(T_i, x_k) = \cdot(T, x_k) + \cdot(P(mode)_n, x_k) + \cdot(P(airport)_n, x_k) + \cdot(P(access/egress)_n, x_k) \quad (7)$$

Finally it has to be stated that most of the strategic analyses shown in the following section are aggregated concerning destinations and trip purposes and that the elasticity's used are documented in Mandel et al (1994), Gaudry et al (1994 a) and Mandel (1999).



## **5. SELECTED STRATEGIC ANALYSES**

To show the effects based on the approach outlined in the sections above we are going to present the reader results on the microeconomic level (of individual consumers) as well as on the macroeconomic level because the evaluation of strategic scenarios has often to be done out of a global point of view. Therefore all simulations are computed regarding the specific consumers' elasticity but most of the results are aggregated and displayed on the macroeconomic level. Despite the macroeconomic orientation of strategic decisions where we focus on situations of competition and the related consumer behaviour which can be influenced by strategic means, we will show the underlying elasticity or response curves to clarify the theoretical background.

For the sake of clarity, the results displayed will be restricted to the geographic shape of Germany although consumer behaviour beyond the German border is affected and of course considered in the computations. Within this section some possibilities of strategic scenarios are shown. All of them are focusing on consumers' reaction to supply changes. Thus the results are reflecting the elasticities of consumers.

The first analyses will deal with the market situation showing the different point of views, from the airport and from the region / consumer. The second part will refer to the interdependencies of air transport and the total transport sector by analysing the problem of airport location and the access/egress systems. The last part will present some simulation scenarios and analyse basic consumer behaviour to *ceteris paribus* supply variations.

In all scenarios the results reflect the interaction of multi-, inter- and intramodal effects due to the applied system approach stated in section 2. Obviously other strategic scenarios can be simulated and evaluated in the same way or even in a more detailed manner depending on the client's needs.

### **5.1. Market situation**

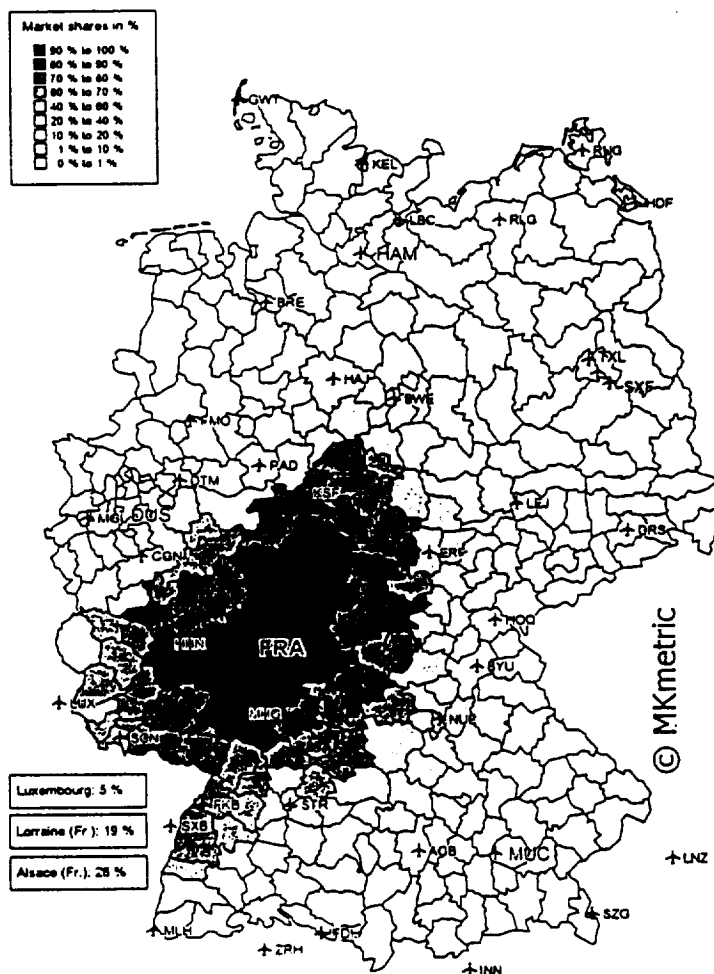
Here we distinguish between two different point of views. Focussing a certain airport because we might be in charge of managing it or regarding the supply situation from a regional scope because we are planning to make a journey or we are e.g. responsible for the regional accessibility of major transport infrastructure.

Both locations are interesting because at the one hand the airport gets a feeling of his market position and on the other hand decision makers will understand more about consumers choice due to the displayed competing alternatives.

### 5.1.1. Catchment area

If the scope of analyses is those of an air transport service supplier, we might be interested in the question where our customers come from. If we ask e.g. for the market dominance of the Frankfurt Airport in Germany, we obtain the catchment-areas by aggregation over regional and trip purpose specific transport flows using the considered airport. The resulting figures show the realised market shares for this airport.

Figure 5 reflects the sphere of influence according to the intercontinental market. Frankfurt as Germany's major hub is offering a large number of long-haul connections, so its market dominance covers a larger area in this market section than in total. Other international airports as Hamburg, Munich, Stuttgart or Dusseldorf are able to claim significant market shares in the domestic and charter segment as well as towards selected destinations abroad.

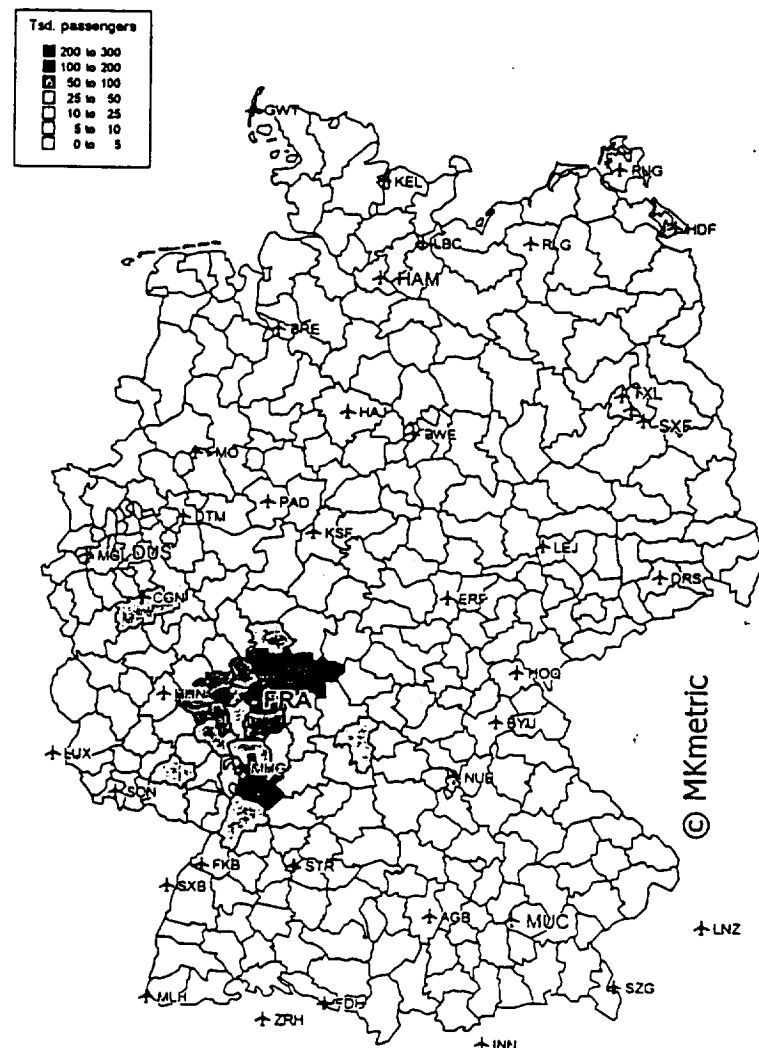


*Fig. 5. Market shares of Frankfurt 1991: intercontinental destinations*

It is obvious that the hinterland of an airport cannot be described by one

or several concentric circles. The shape rather depends on specific characteristics of the airport and its competitors, like number of destinations and flights offered or the accessibility by earthbound feeder systems. So the catchment area (to all destinations and with more than 10% share) of Frankfurt extends to 600 km in the north-south direction, while in east-west direction only to 300 km. Of course the catchment area exceeds the German borders but the main access lines by the land based modes are in north-south direction. For the sake of understanding all figures are restricted to the shape of the German borders.

Referring to the last subsection, you will find in the scenario 'route inauguration' the catchment area of Frankfurt for the North American Market (figure 18). Comparing these catchment areas it is obvious that they vary according to the market, as they are an endogenous result of the system approach which takes into account the market specific competition of airports / air services.



*Fig. 6. Passengers at Frankfurt by origin for intercontinental destinations  
1991*

If we substitute the regional market shares in figure 5 with the absolute number of passengers the spatial demand pattern for Frankfurt Airport gives deeper insight in the market potentials (figure 6).

Beside the extended area of Frankfurt and the densely populated counties south of it, where most passengers are originating, a remarkable number of people are withdrawn from other metropolitan areas in Germany, although there are international airports in those counties (e. g. Cologne, Hanover).

In the next figure we compare the different spheres of influence of four German airports situated quite close together in the high populated region "Ruhrgebiet". Market shares shown are a forecast for the year 2004 to/from all destinations. The first two airports Cologne (CGN) and Dusseldorf (DUS) offer a huge number of destinations served by non-stop-flights, not only inside Europe, but also to some intercontinental airports. In addition almost every holiday destination throughout Europe as well as some of them in other continents are connected to Dusseldorf and Cologne by non-stop or at least direct flights. The other two airports Munster/Osnabrueck (FMO) and Paderborn/Lippstadt (PAD), offer only a few international destinations to selected hubs like London and Amsterdam. They focus on domestic air transport and charter flights for holiday trips to destinations around the Mediterranean Sea.

The market shares in the counties situated quite close to the airports are a result of the available destinations offered. In case of Dusseldorf and Cologne shares reached go up to a maximum of 80%, while Munster/Osnabrueck and Paderborn/Lippstadt can realise only values up to 60% resp. 40%.

In addition, Cologne and Dusseldorf can be reached by urban mass transit as well as by high speed trains, while the level of service in public transport to Munster/Osnabrueck and especially to Paderborn is quite poor. Together with the lack of destinations compared with DUS and CGN, this influences the total size of the catchment area of an airport. So both, Dusseldorf and Cologne have market shares of almost 40% in the Paderborn area and still almost 20% in the Munster area, while in comparison to that Munster/Osnabrueck and Paderborn/Lippstadt do not gather any passengers from the Cologne or the Dusseldorf county.

Finally, from this catchment areas, one can see, how hard different airports compete. In case of the Dusseldorf airport, market shares decreases by more than 30% between adjoining counties towards the airport of Cologne. The same holds for Cologne's sphere of influence towards DUS, while to other directions the specific market shares decrease more moderate.

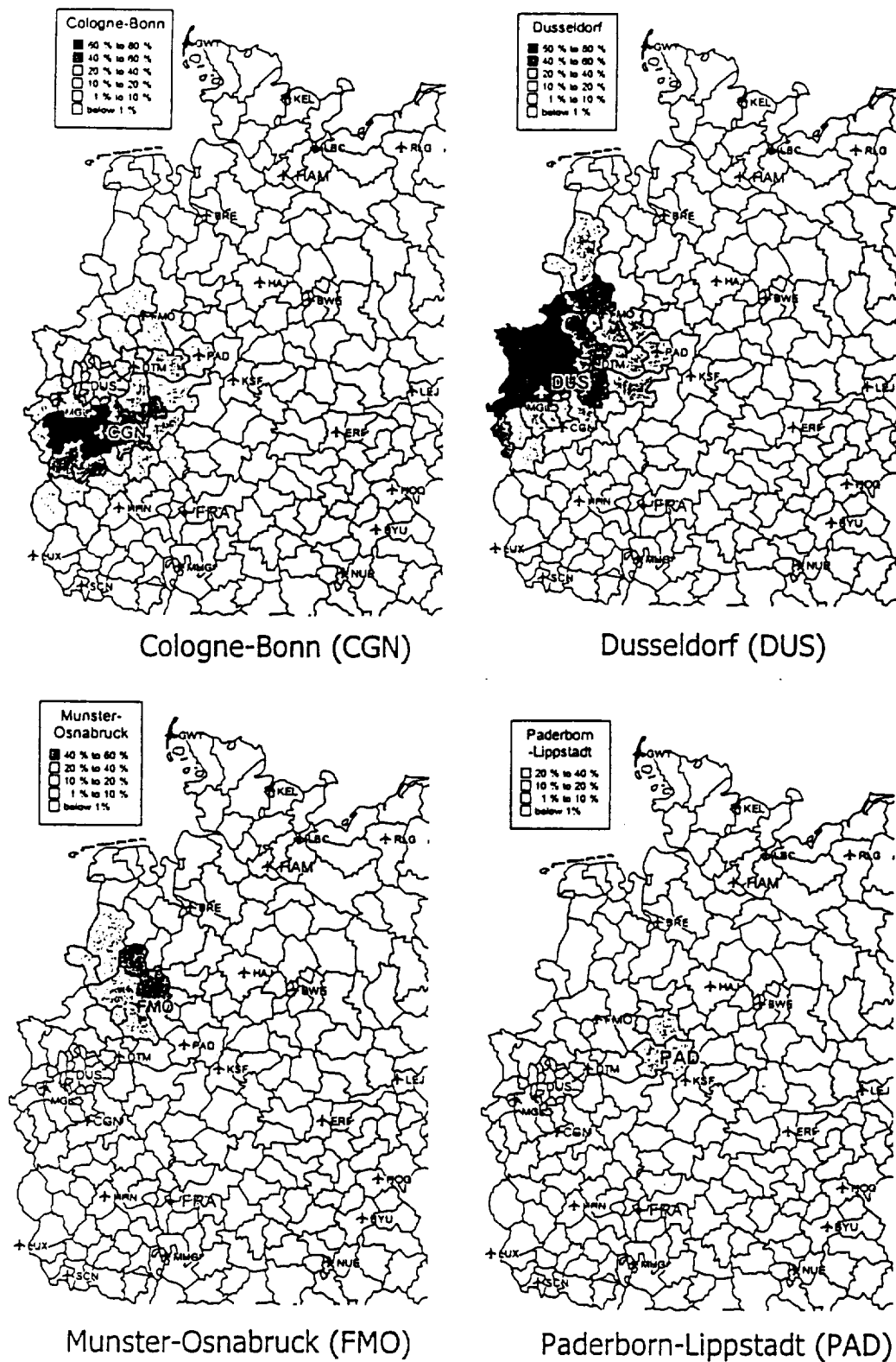


Fig. 7. Market shares at four different Airports; forecast 2004

### 5.1.2. Regional differences

Coming back to the question why airport choice has to be considered a small example (from 1991) will demonstrate the choice problem a consumer faces and which even become more difficult in a liberalised air market with capacity constraints at different airports.

Comparing two German business travellers - e.g. one living in famous Heidelberg (county) and the other one in the neighbouring county of Karlsruhe - their decisions concerning the chosen airport for a trip will vary. If we neglect possible individual preferences a set of external factors influences their choice between possible starting points for a flight. If we study trips destined for e.g. North America (see fig. 8) we will find that the probability to travel via Frankfurt-Main Airport for both travellers is around ninety per cent. This is not very surprising due to the fact that Frankfurt dominates the German market as the largest hub and being the homebase of the national carrier Lufthansa.

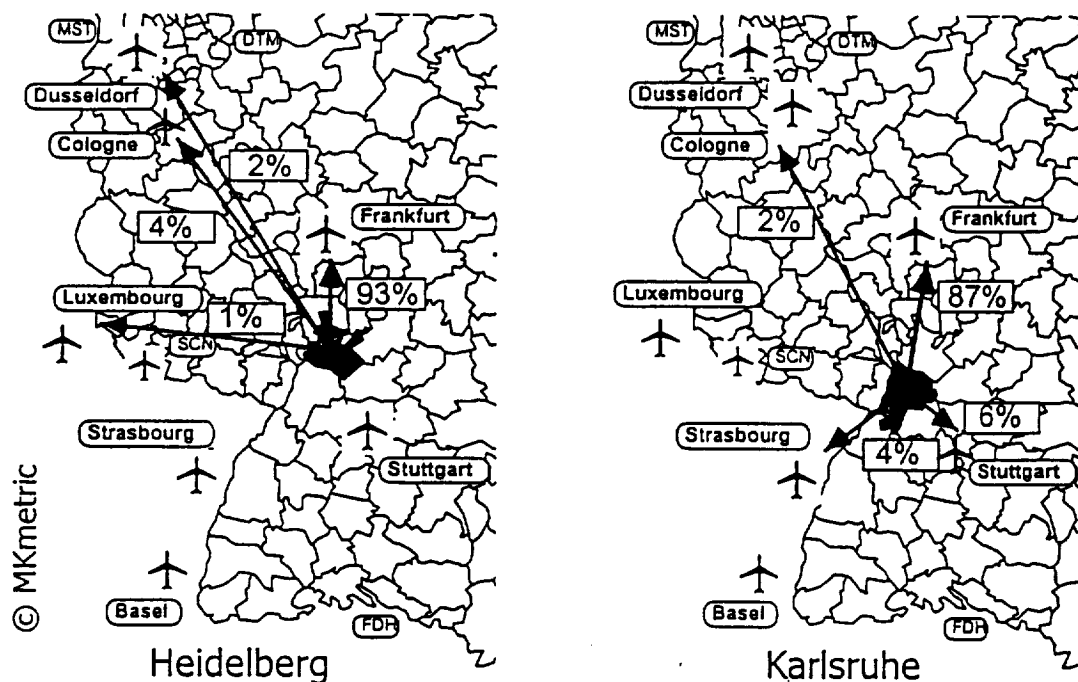


Fig. 8. Airport choice, destination: North America, trip purpose: business

Much more interesting are e.g. the probabilities to choose alternative airport for business trips crossing the Atlantic. As described in the sections above the choice of airports is determined by a set of factors including accessibility, offered frequencies and destinations. The figures above shows how the combination of these factors influences the probability to choose one of the remaining alternatives for such a trip. While the airport characteristics are equal in both cases the accessibility by private and public

transport differs. In general it was found that business travellers prefer strongly the airport, which offers the highest flight frequencies and the shortest duration of the whole trip, including access and egress.

When analysing vacation trips one observes a completely different choice structure for the travellers in the example above. Due to lower restrictions in time but higher price sensitivity holiday-makers prefer the most convenient kiss&fly-access to possible airports offering non-stop or via flights to start their journeys but they are also open to choose other alternatives as long as the price differs significantly. Figure 9 depicts the choice probabilities for holiday travellers from Karlsruhe and Heidelberg, respectively, to an Italian destination.

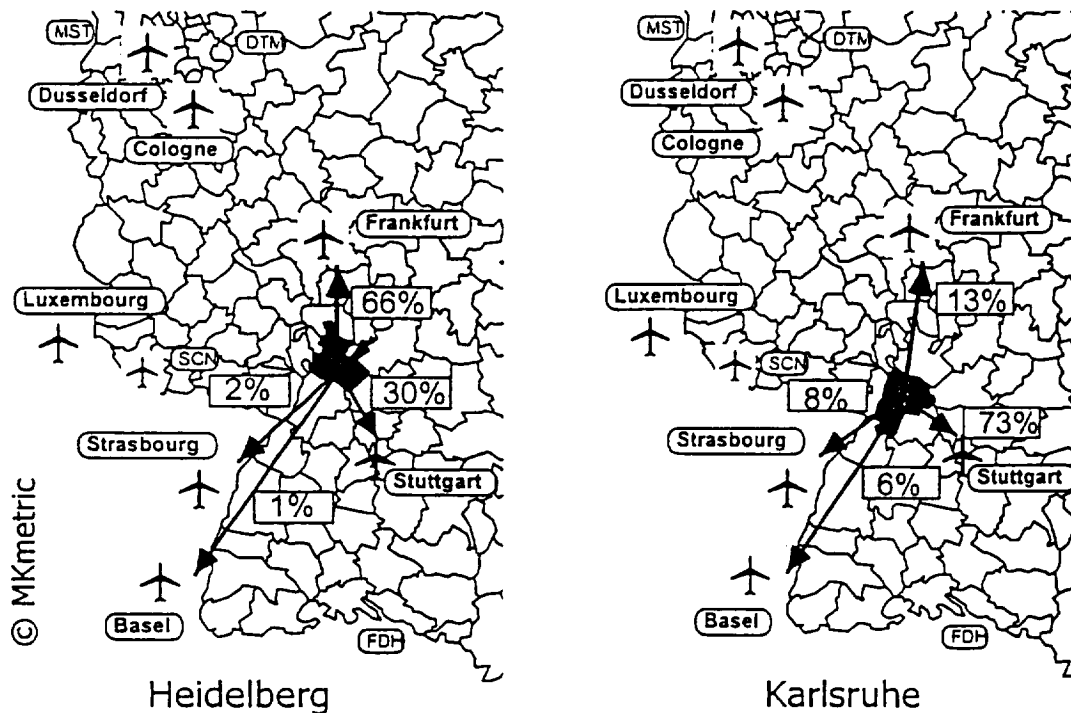


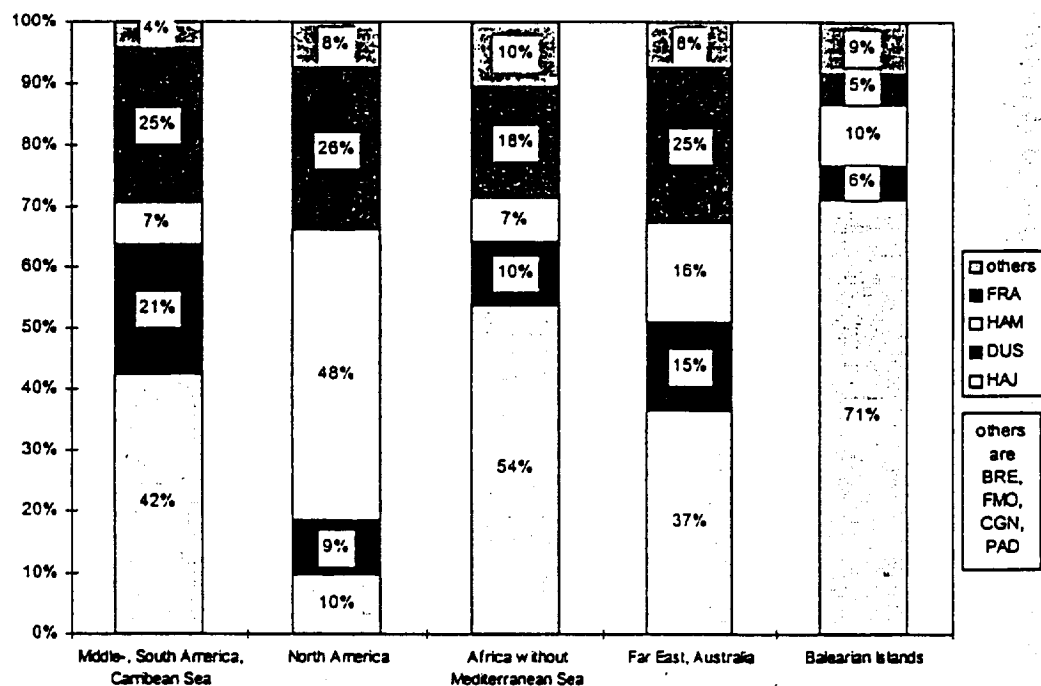
Fig. 9. Airport choice, destination: Rome (Italy), trip purpose: vacation

Major differences rise from other characteristics, namely the distance between the origin and the airport or the availability of a non-stop flight (even if only once a week) or the accessibility by public transport. So travellers from Karlsruhe prefer strongly Stuttgart Airport. Frankfurt, which is situated additional 50 km away, can only attract a market share of 13%, although much more flights are offered than in Stuttgart. Due to a missing non-stop-flight to Rome, only 8% remain for Strasbourg Airport, despite the fact that it is the nearest one to the area of Karlsruhe county.

When starting a holiday trip from Heidelberg, Frankfurt is certainly the best choice for two third of all vacation travellers. But the second best alternative via Stuttgart gets still 30%, while choosing other airports as e.g. Strasbourg or Basel will be an exception.

For the sake of understanding only this small example of Heidelberg and Karlsruhe was presented. By the way, in the meantime (1997) in the area of Karlsruhe a regional airport (Baden-Airport) opened and already offers interesting services to tourist centres which unfortunately could not be taken into account for these examples based on 1991. Of course such examples can be extended when one moves to areas where a lot of services and airports are competing, like in the Rhein-Ruhr, Berlin, Paris or London area, and one analyses all possible destinations and alternatives. Some analyses follow below

After we saw, how people from to different counties chose their airport, we now depict on a single area and compare differences in airport choice depending on the passengers destination. Figure 10 shows the market shares for some destinations, different airports can realise in the Hanover area. Here consumers airport choice is shown for the trip purpose “vacation”. Analysis can be done as well for other trip purposes, destinations or regions.



*Fig. 10. Airport choice from the county of Hanover to different destinations 1991*

This airport choice differs, strictly depending on

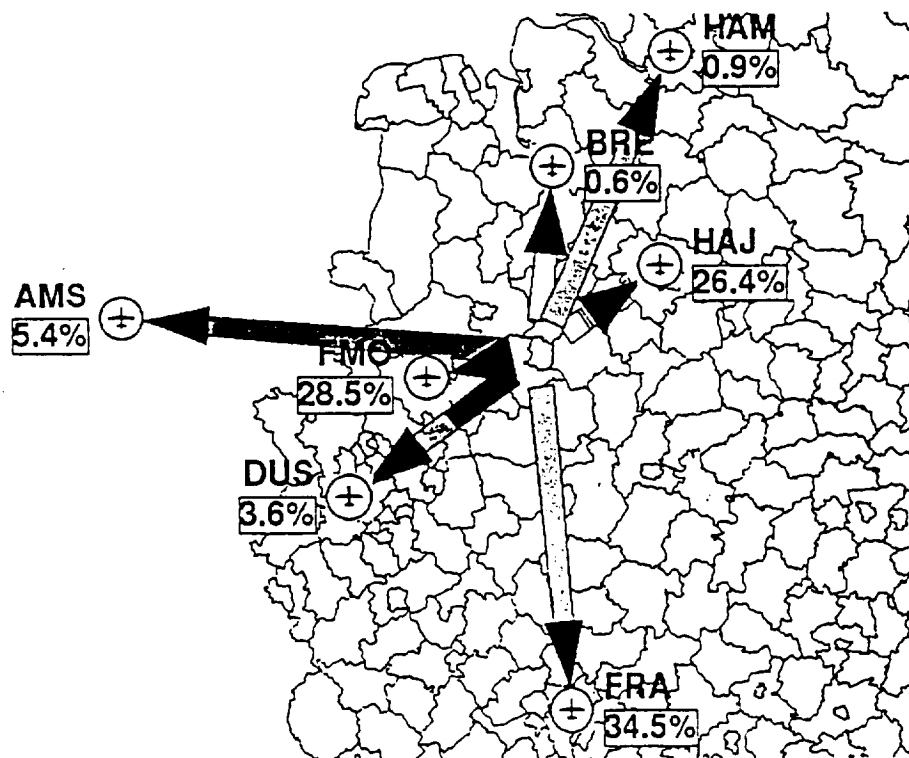
- availability of non-stop-flights to the specific destination at the airports,
- distance (travel-time) between the county and the different airports,
- price for the flight to the specific destination from the airport and the costs of access/egress,
- total travel-time (access/egress, check-in/out, flight-time)
- frequency offered on the specific routes offered at the airports.



So as an example people from the area of Hanover chose Hanover Airport for holiday-trips to the Balearian Islands with a probability of more than 70%, due to access/egress plays a major role on such a short-haul flight. In addition non-stop-flights to that destination are offered at Hanover Airport with high frequency.

On the other hand passengers from that area travelling towards North America prefer the Frankfurt Airport (48%), as the prices offered there to that destination in average bet the costs from starting at Hanover, including the railway fare when using the available high-speed trains Hanover – Frankfurt. Additionally in this case the consumers more accept an exceed of time for access/egress to Frankfurt, due to the longer total travel-time on such long-haul trips.

The next possibility to analyse the regional / consumers' point of view concerns the competing alternatives considering the different transfer locations. This analyses is based on the principle idea shown in the beginning but allows in addition to show hub-potentials, if an aggregation over all regions to one destination is computed. Anyhow to understand the principle one example is selected which shows the competitive situation from Bielefeld to Hong Kong in 1994. By the way Bielefeld is located south-west of Hanover where the EXPO 2000 will take place.



*Fig. 11. Airport choice from Bielefeld to Hong Kong, full fare business class, 1994*

The influence of pricing strategies (which will be shown in the last subsection of this paper) upon the hub potential is obvious if one compares Amsterdam and Hong Kong, whereby the situation of the latter changed due to the new airport and the much higher fees / charges.

From Bielefeld towards the destination of Hong Kong, full fare business class (NTP)-passengers in majority prefer flights from the two nearest available airports (Hanover-HAJ and Munster/Osnabrueck-FMO) although no non-stop or direct flights are offered there. Another third of all those passengers take the route via Frankfurt (FRA), as it is equipped with non-stop flights to Hong Kong and Frankfurt can be reached in almost adequate time by rail or road. Amsterdam (AMS) can still realise a market share of more than 5%, although it is quite far away, but can be reached by rail in a good way and offers non-stop-flights as well as Frankfurt. The rest of the shown alternatives are only rarely chosen, as they neither offer non-stop flights nor those airports are situated very close to Bielefeld.

*Table 1. Airport choice from Bielefeld to Hong Kong, full fare business class, 1994*

Alternatives	origin from	via 1	via 2	destination	share for full fare business
1	FRA	----	----	HKG	34.5
2	AMS	----	----	HKG	5.4
3	HAJ	CPH	----	HKG	3.3
4	BRE	CPH	----	HKG	0.6
5	FMO	FRA	----	HKG	28.5
6	HAM	CPH	----	HKG	0.9
7	DUS	CPH	----	HKG	1.2
8	HAJ	ZRH	----	HKG	3.0
9	DUS	ZRH	----	HKG	2.4
10	HAJ	FRA	----	HKG	20.1

In table 1, we can focus on the stop-over connections and the hubs people change plains. Here the consumer prefers flights via Frankfurt, offering good connecting times, due to the high frequency of the feeder flights from FMO and HAJ to that hub. This two alternatives already form 48.6% of the 54.9% passengers using FMO and HAJ at all. Other hubs chosen are Zurich (ZRH) and Copenhagen (CPH). As we regard the full fare market sector, other big European hubs like London or Paris do not play any role, due to their geographic situation according to the Germany – Hong Kong routes. It has to be remarked that no alternative with two stopovers has been selected and we just display ten alternatives which summed up to 100% although there are plenty more possibilities. It is also obvious that the same analyses for economy class will show another preference of alternatives, e.g. share distribution.

## 5.2. Interdependencies

This subsection will show the interdependencies of air transport with the total transport sector. It will be obviously that decision makers have to consider the overall framework to know all influencing factors to minimise the risk in strategic planning. Based on an existing case study, choosing a location for an airport, we analyse the total passenger demand, modal split and access/egress effects. Finally two examples will analyse the public access/egress mode.

### 5.2.1. Location of an airport

Mode choice, airport choice and access/egress choice as a part of a traffic forecast can help to come to a decision where to place a new airport best. The comparison of five locations for a new airport near Berlin on several points of view will be shown in the following figures.

A set of locations has been evaluated with respect to different measures. All considered alternatives are located in the south respectively south-west of the German capital. The corresponding scenarios cover beneath the single airports also two airport systems that are combinations of Tegel and Schoenefeld as well as Jueterbog-W. and Schoenefeld. The figure 12 depicts the five different locations considered.

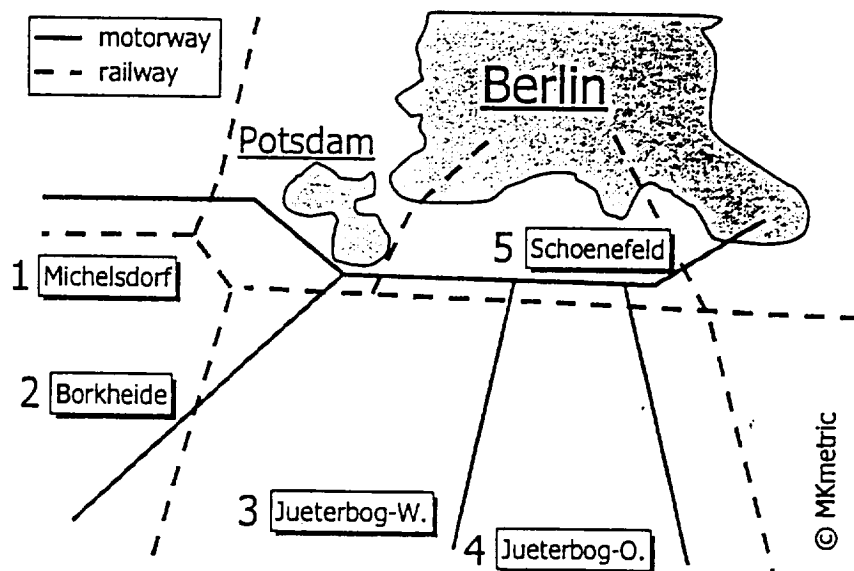


Fig. 12. Comparing locations for an international airport for Berlin

Various indicators could be assessed to evaluate the relevance of certain airport locations. Regarding to economic aspects decision makers are forced to compare the alternatives based on the number of passengers that are going to choose the airport when doing a journey.

As travellers are making their choice not only between different airports but also are able to take a land-based transport mode the resulting demand figures could not be evaluated in the unimodal context of the air service system. Nevertheless the total passenger figures are essential indicators for economic evaluation.

Figure 13 shows the number of passengers forecasted for the year 2010 in seven scenarios. The highest number of passengers can be expected, when a system of two airports will be operated: One close to the city, serving national short haul flights and routes to some important European capitals.

The other is situated up to 60 km from Berlin's city centre. It is more assigned for long, especially intercontinental hauls which covers also pure charter flights and direct flights to destinations, where the demand, originated at Berlin, has to be fed by national commuter-flights to provide satisfactory load factors (hubbing). At this stage we did not analyse the hub potential in detail as shown in the last subsection because here it is more important to ensure a 24 hour service and to avoid capacity restrictions at the airport itself as well as in the air corridors.

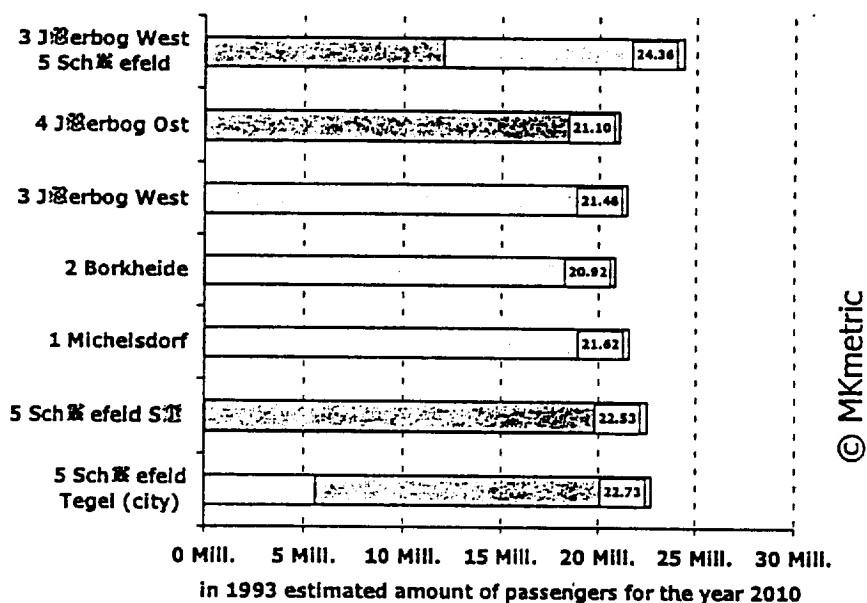


Fig. 13. Passengers Berlin 2010 depending on airport's location

From a macroeconomic point of view the modal split is also an important measure. Infrastructure investments in Germany must be evaluated according to well-defined evaluation schemes. Herein the investor must apply cost benefit analyses beneath others. These processes require very detailed figures to assess a set of related impacts. Figure 14 depicts as an example the resulting mode choice pattern on the relation Berlin-Munich in the year 2010 for the set of potential locations.

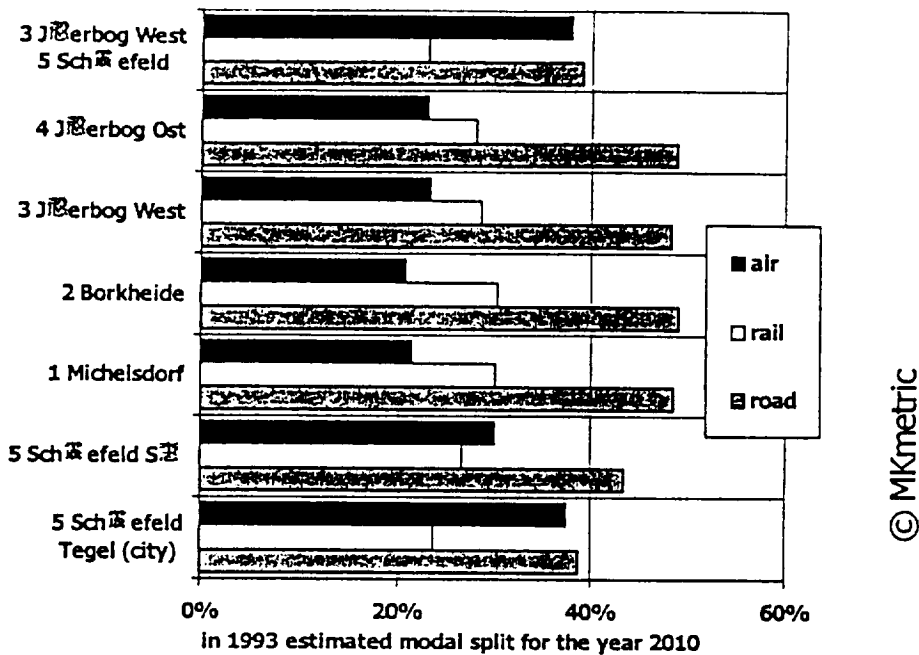


Fig.14. Modal split between Berlin and Munich 2010 depending on the location of an airport

Highest mode choice for air transport is given when there is an airport near Berlin's City centre, like Tegel or Schoenefeld. Market shares up to almost 40% can be expected then. On the other hand, when Berlin's new airport is situated about 50 km, the share of travellers by plane between Berlin and Munich decreases to about 20%. Obviously, the time needed to access the airport plays a major role on such short haul route.

Regarding the environmental point of view decision makers will be also interested in the impact on natural and cultural resources. Measures for this field of interest could be derived e.g. from the modal split figures concerning the access and egress modes. Especially in dense populated areas as well as ecological sensitive areas the share of passengers using public transport for their ways from and to the airport are useful indicators. Pollution could be directly derived from the absolute demand figures when applying distance related emissions to it.

So when comparing several locations for a new airport regarding the change of passengers mileage in comparison to the status quo situation is a need. Separated by the different modes for access and egress as well as for air transport, conclusions concerning energy consumption, vehicles emissions and noise can be drawn. This allows to set up some basic data for an environmental assessment concerning the different possible locations for a planned airport. Here (figure 15), airport locations with a large distance to the city of Berlin cause an increase of passengers-mileage up to 0.64 billion passenger-kilometres, although passenger-mileage of air transport

diminishes in this cases, as air transport will lose some passenger on short-haul flights. On the other hand a new 'single' airport quite close to the city will cause a slight decrease of passengers mileage when sum up all modes. In this case passengers mileage of air transport rises up, while earthbound feeder transport to the airport goes down. Airport systems with one airport close to the city and a larger airport far off Berlin, have no remarkable influence of passengers mileage.

Such an environmental analyses can be extended by computing the aircraft movements according to starting/landing routes divided into aircraft categories ( ICAO chapters). This allows to generate the noise distribution.

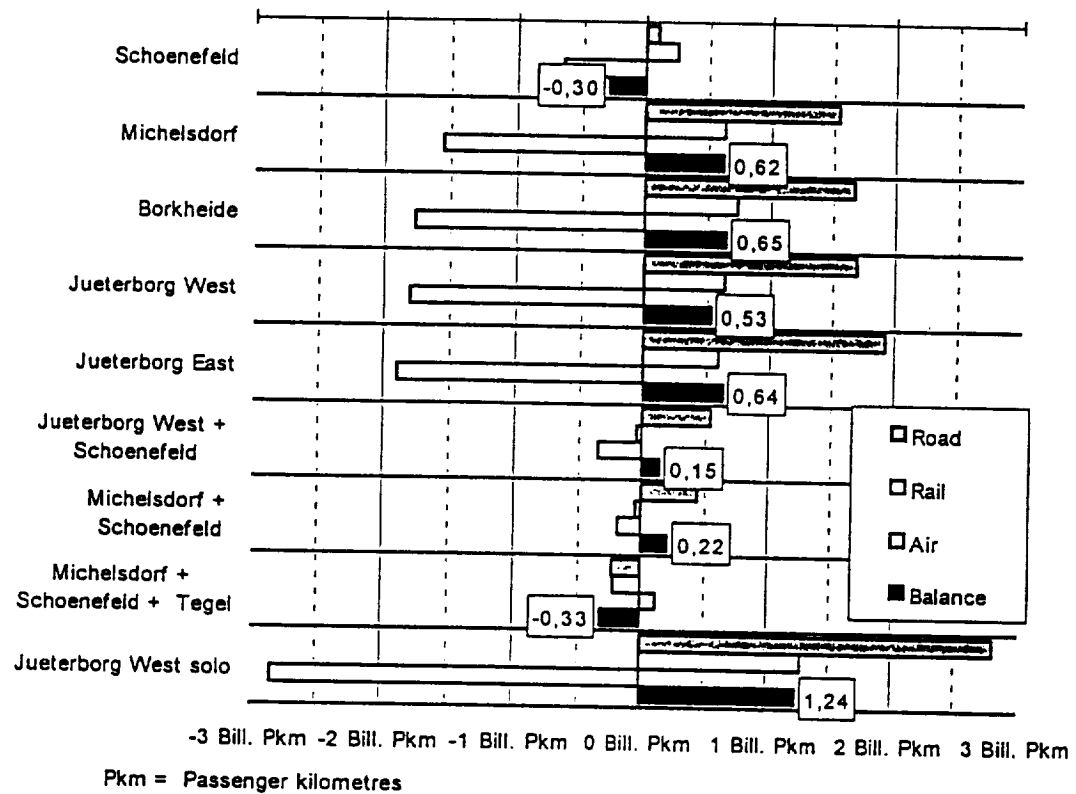


Fig. 15. Change of passengers mileage depending on an airports location

### 5.2.2. Accessibility of an airport

In line with the Berlin example in the previous subsection the access/egress diversions of the public and individual transport modes were analysed.

Modal split and assignment to feeder links for the new planned airport play a significant role when comparing several possible locations for a new airport.

So, in the tables below one can see the number of passengers expected at the year 2010 on rail and road links to a new airport for Berlin, depending on its location. Scope of such a study is,

- acceptance of airport-express-trains by the passengers, when the airport is situated quite far from the city,
- additional capacity requirements on existing road links,
- necessity of additional roads to the airport,
- necessity of linking the airport to the forthcoming high-speed railway network in Germany.

*Table 2. Access/egress choice road*

Trips in mill. Scenario	from the direction of Berlin	from West	from East	total each Airport
Reference: Tegel and Schoenefeld				3,70
Schoenefeld South				9,12
Michelsdorf	8,39	0,80	0,08	10,93
Borkheide	7,54	0,52	0,26	9,27
Jueterbog West	7,27	1,20	0,26	8,32
Jueterbog East	7,23	1,14	0,24	8,74
Jueterbog West and Schoenefeld	2,87	1,06	0,23	8,60
				4,16
				8,33

*Table 3. Access/egress choice rail*

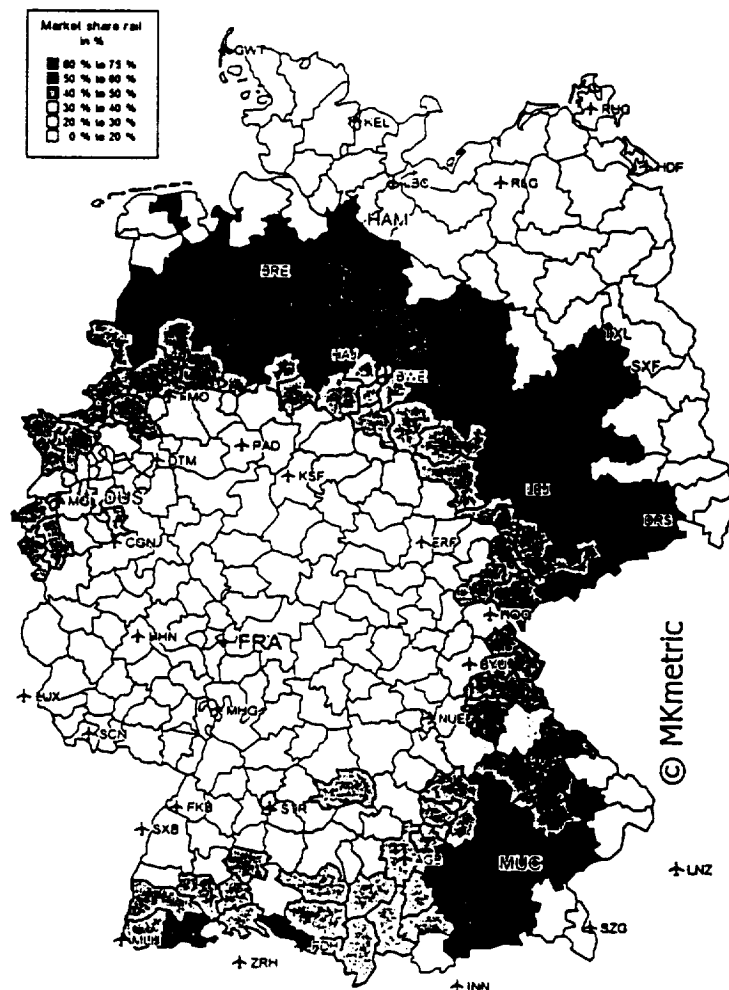
Trips in mill. Scenario	To/from Berlin Airport-Express	Other directions with IC/ICE	Other directions with regional trains	total each Airport
Reference: Tegel and Schoenefeld				1,90
Schoenefeld South	6,69	0,17	0,10	4,05
Michelsdorf	6,44	0,20	0,07	6,96
Borkheide	6,86		0,18	6,71
Jueterbog West	6,86	0,45	0,18	7,04
Jueterbog East	6,74	0,42	0,17	7,48
Jueterbog West and Schoenefeld	3,47	0,44	0,17	7,33
				4,08
				3,44

The main results were (with some differences between the specific airport locations) the

- high acceptance of airport-express-trains, increasing with the distance to the city,
- passengers flows to / from Berlin strictly dominate the total passenger demand,
- connection to high-speed trains is useful when the airport is located in the south of Berlin (towards the agglomeration of Leipzig / Halle,

Of course to evaluate such results in detail requires the necessary service characteristics, e.g. the public service frequency, which would exceed the limits of this paper.

Due to the linked models for access/egress, one can analyse the number of passengers arriving at the airport by public transport. Compared to the previous figure one can see that the airport-railway station (high-speed intercity connections) has great impact on the access mode share.



*Fig. 16. Market share of rail Frankfurt Airport 1991*

In 1991 the airport of Frankfurt already had one railway station close to the terminal. So the airport is connected to the Intercity-Network of the Deutsche Bahn AG. Beside this, the airport is also served by suburb trains. So using rail to reach flights starting from Frankfurt is quite common, as you can see in figure 16. The market share of rail to Frankfurt Airport raises up to a maximum of 75%, according to the distance to the origin of the passengers trip. A second railway station allowing more high speed trains to serve the airport of Frankfurt has just come into service in May 1999.



Another point of view in analysing railway traffic to an airport is to show the number of people using trains to Frankfurt airport by regions, as we did that in figure 17. Many of the travellers start their trip in the hinterland of Frankfurt — although, there are also a remarkable number of people using ICE-trains along the high speed link Hamburg – Hanover – Frankfurt – Karlsruhe – Basel to reach Frankfurt's Rhein-Main-Airport. Even from Berlin, which is more then 500 km far away, about 100 Tsd. people per year take a train to Frankfurt Airport.

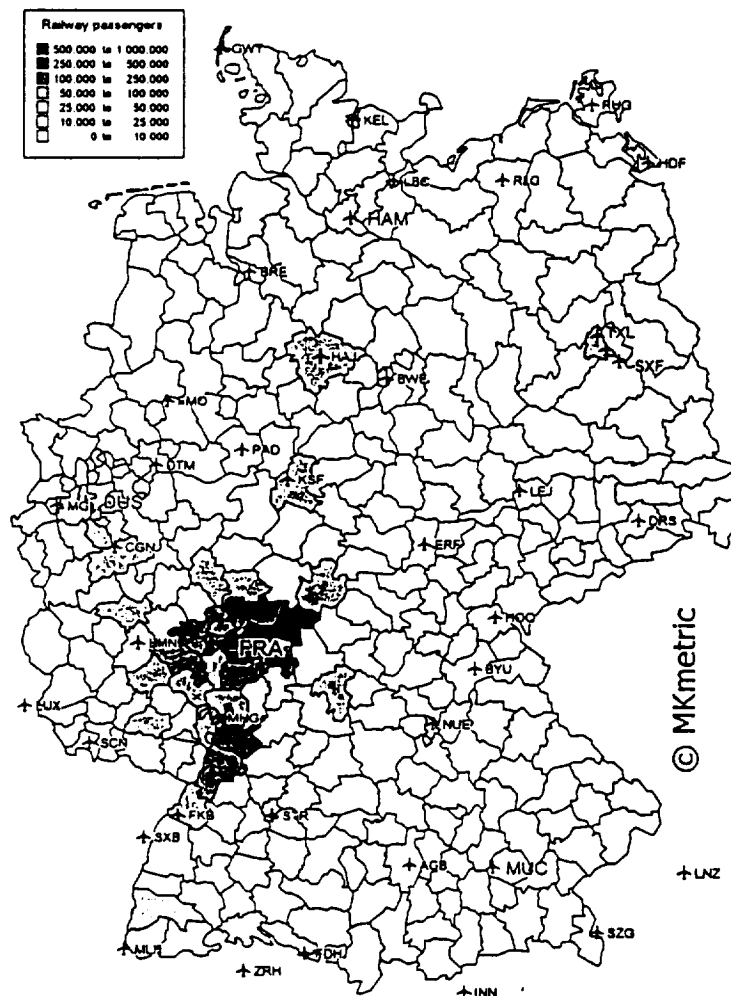


Fig. 17. Passengers to Frankfurt Airport by rail 1991

Train operators can also be interested in origin and destination of railway users to or from an airport. In such a case more detailed information is needed. As an example therefore, the assignment of railway traffic to and from the Leipzig Airport, when equipped with an own railway station at the planned high-speed-link between Erfurt and Leipzig, is shown in the figure 18. Assigning railway traffic to an airport helps to answer questions like

- Which towns have to be connected to the airport by direct trains?
- On which lines existing trains offer sufficient capacity for the additional traffic?
- Where have additional trains to be put into action, due to the increasing number of travellers?
- Which revenues can be expected from serving an airport by rail?

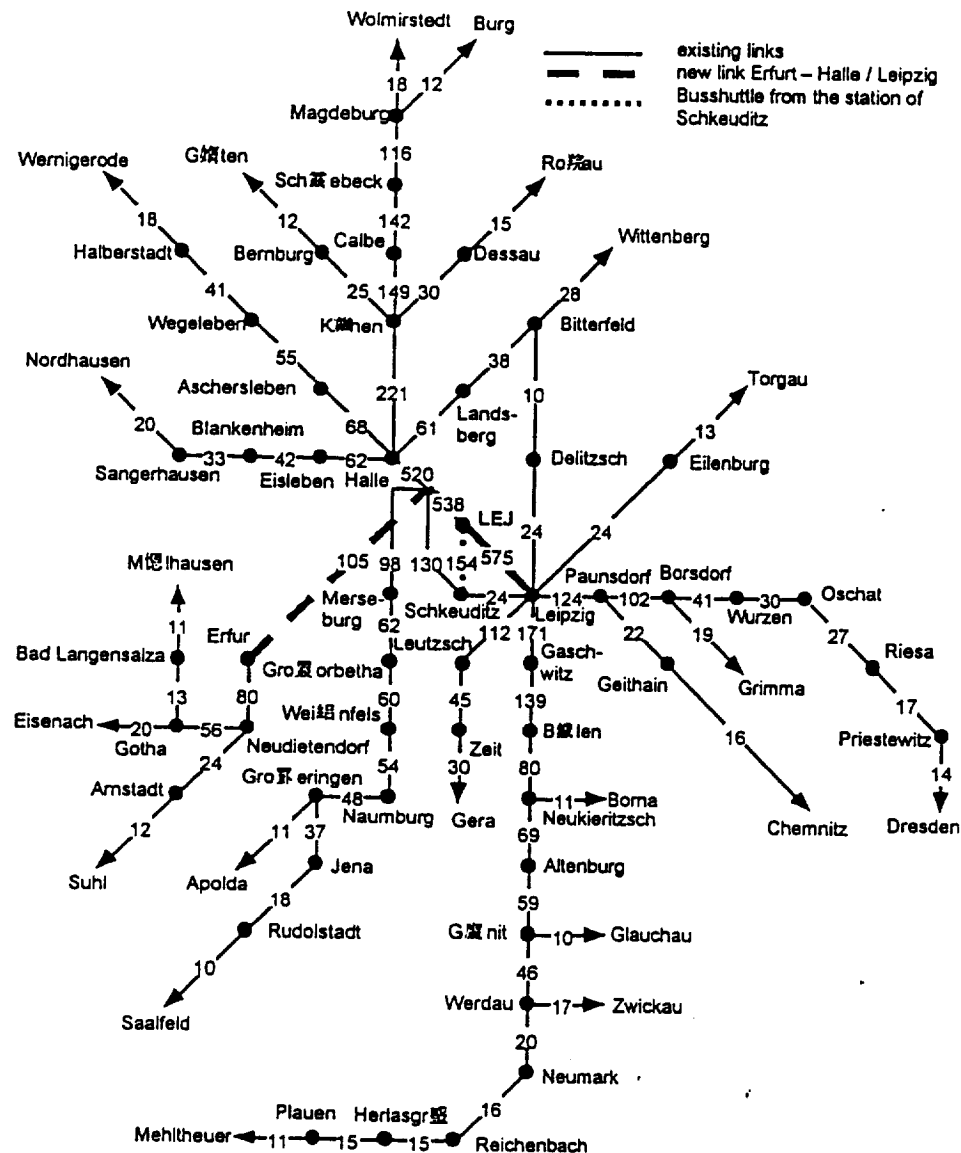


Fig. 18. Passengers (in thousand per year) by train to/from Leipzig Airport, 2015

### 5.2.3. Scenarios

The last subsection presents some scenarios where the first and the second example are dealing with a network change of air services and its

impact on airports. While the first one is very simple and restricted to the inauguration of a new route at Berlin with the intention of showing the effects on the major competing airport in this market area, the latter example is quite complex in the actions considered and will show the effects on both airports involved. The third and fourth example are focussing on consumers elasticities due to *ceteris paribus* fare variations. While the third one presents the elasticity curves for different markets and trip purposes the last example displays a pricing strategy based on the elasticities stated in the third example.

#### **5.2.4. Route inauguration**

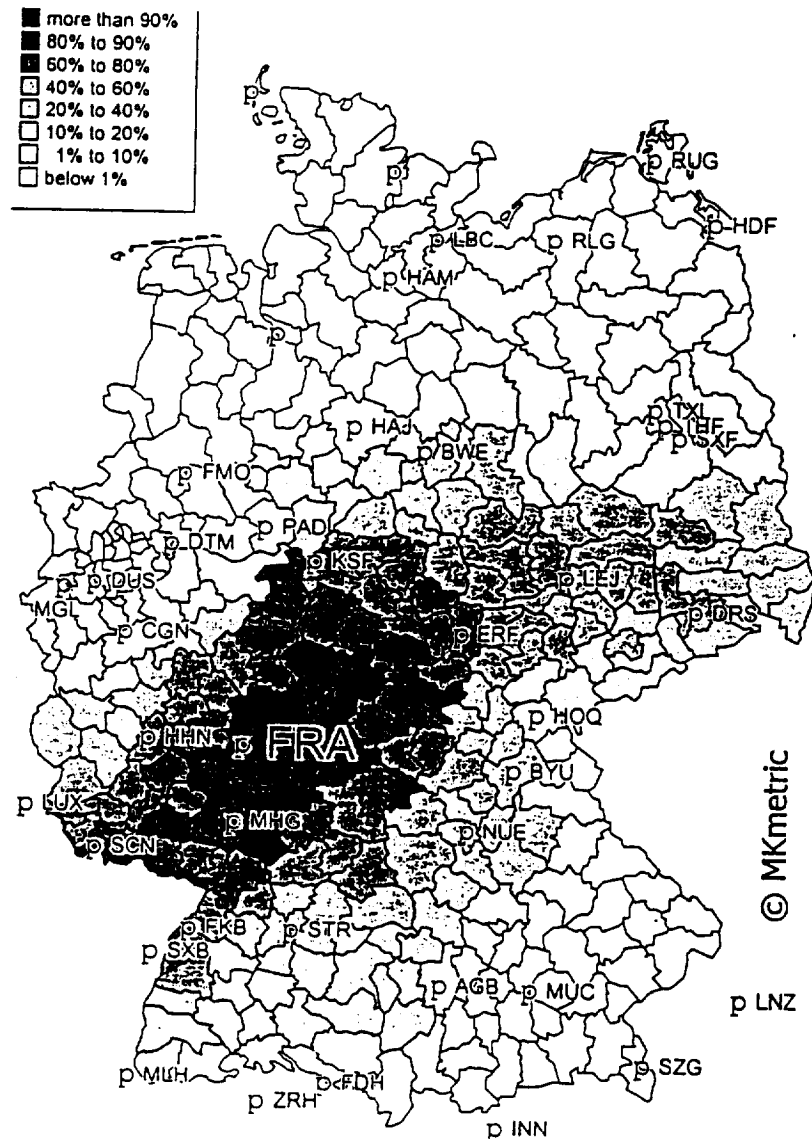
The German airport that serves the North American market the most is without doubt the Frankfurt/Main airport. This airport hosts the homebase of the former national carrier 'Deutsche Lufthansa AG' and is 'the hub' in Germany. As our scope is on consumers' behaviour in a competitive environment we want to study the impacts of changes on the supply side. Therefore the first step is to get an impression of the competitive situation of this major airport, which is displayed in form of Frankfurt's catchment area by Figure 19.

As Frankfurt is offering a large number of services to North America and the earthbound access/egress possibilities are above average, its market dominance covers a wide area of Germany. The white spots at Frankfurt's hinterland do not indicate that Frankfurt doesn't play a role in consumer decision they just reflect on the one hand the good air feeder system to Frankfurt, which is used as access alternative instead of the landbased modes, and on the other hand the strong influence of competitors - e.g. non-stop service at the airport or other routes via competing hubs.

Considering the status quo air network, an additional non-stop air service from Berlin to North America is installed in this scenario. The point of interest we want to show is the consumers' reaction to a new competing alternative which enriches the existing set of possibilities. Here the question about the demand elasticity plays a key rôle when arguments between airlines and airports are exchanged whether the originating market is big enough to install such a new service or not. Of course the transfer passengers will also partially use the new service, but for an airport manager it is more interesting to attract new customers than to shift air passengers from one flight to another. Obviously airlines will take another point of view. May be they compete with another airline and want to increase their market share or they want to enrich their service by another O-D pair without losing the economic surplus at the already existing service of this market area. To analyse such effects we refer to the already discussed alternative or hub

analyses in the second subsection. Anyhow for both groups it is important to know how the travellers react to service changes.

Although Frankfurt Airport and the Berlin airport system (TXL, THF, SXF) are already quite far from each other, the catchment areas for originating/destinating passengers are overlapping with up to 10% Berlin travellers using earthbound systems to access Frankfurt. The majority of travellers (90%) are choosing transfer services offered at Berlin via airports like FRA, AMS, LHR and CDG. Now the question is whether this situation can be influenced by an airport located at the border lines of Frankfurt's catchment area.



*Fig.19. Market shares of Frankfurt Airport: destination North America*

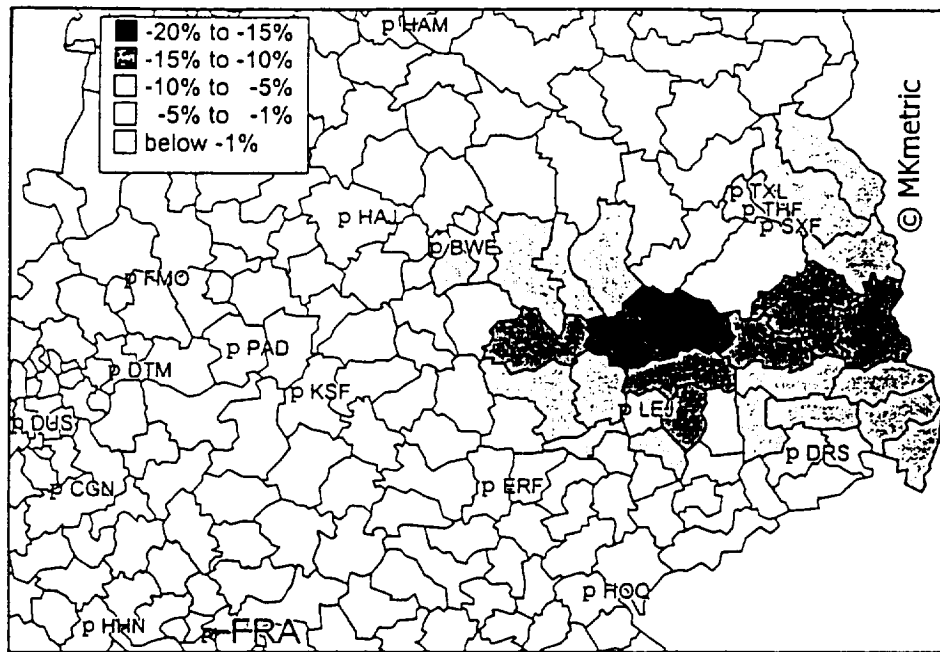


Fig. 20. Market shares changes of Frankfurt Airport by regions if non-stop flights to North America are offered at the Berlin airport system

In figure 20 we simulated the consumer reaction, when new non-stop flights to North America are offered at the Berlin airport system out of the point of view of Frankfurt Airport. As indicated in figure 20, Frankfurt will lose market shares in some areas belonging to Berlin's sphere of influence. The maximum decrease doesn't take place in Berlin directly — although the decline is up to 10% points which nearly diminishes Frankfurt's market share to zero — but in two counties situated in the south-west of Berlin where losses reach up to 20%. The reason for this strong reaction can be found in analysing the consumers' alternatives for reaching a destination in North America with and without non-stop flights offered at Berlin. Comparing the alternatives, consumers are making their choice in respect to their e.g. price and time elasticity which now results in passenger shifts to the new service at Berlin withdrawing them from Frankfurt.

This reflects the obvious rule that the closer the starting-point of a trip is to an airport, the more people prefer this airport even if then a transfer on their trip is needed, especially if the next airport offering non-stop flights to their final destination is far away. The main area of competition is at the regions where no airports are located.

So travellers not originating in the vicinity of an airport have to compare very carefully their impedances to airports which offer non-stop flights to their final destination and the ones who do not. If e.g. the difference in travel time is less than or equal to the time it affords to change a plane, they will choose the new opportunity. So in the case of additional destinations for non-stop flights being introduced to the market, people react more sensitively to a new alternative by changing their starting airport. Figure 19

points out that Frankfurt's market share was up to 40% in such regions as the south-west of Berlin, although there were other airports closer situated but without a non-stop service to North America. The introduction of a new service at Berlin reduced Frankfurt's market shares by half as shown in figure 20.

It has to be stated that the results differ by trip purpose and final destination so that the results shown are aggregated. In addition one has to be aware of the underlying access/egress infrastructure which is also mirrored by the catchment area of the airports.

### **5.3. Secondary hub**

After the quite simple example a), a bundle of supply changes take place in the strategic scenario b). We assume that in addition to Frankfurt Airport a secondary hub in Germany at Munich airport will be established. The scenario consists of the following changes to the situation of the year 1991:

1. New additional intercontinental destinations are offered at Munich.
2. The feeder network is extended to strengthen Munich's hub potential.
3. Some secondary destinations, offered in Frankfurt, are cancelled due to capacity constraints in favour of more flights to destinations with higher demand.

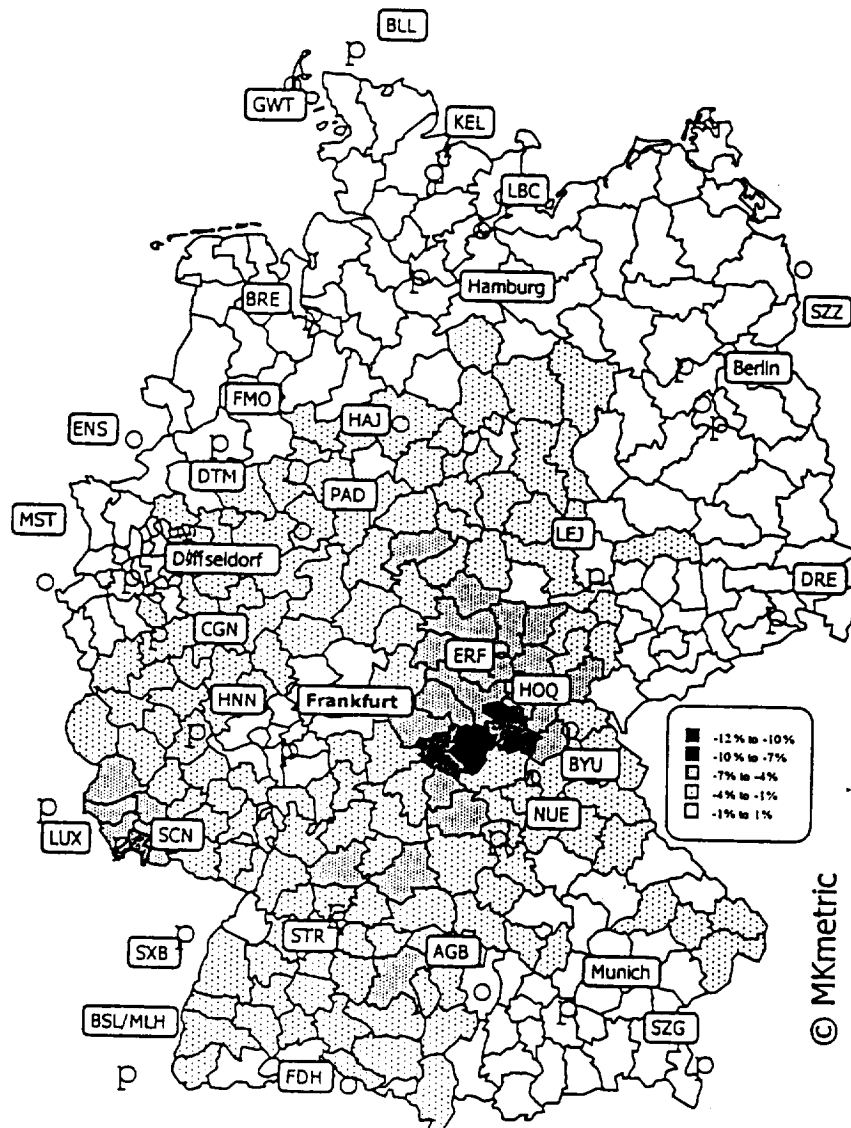
Such supply changes create a new competitive situation between the airports Frankfurt and Munich where also other international airports are affected. In the following, we will focus just on the two airports Munich and Frankfurt. At first the changes in passenger volume at the two airports should be mentioned. While Frankfurt is losing 0.7 Mio., Munich gains 1.6 Mio. passengers in total and on intercontinental routes Frankfurt loses 0.15 Mio. which nearly can be attracted completely by Munich. Now it is interesting to know how these passenger shifts can be explained e.g. what was the consumers behaviour?

How consumers react in respect to the new situation can be summarised by the following five possibilities:

1. Travellers who used to depart from Frankfurt, now take off at Munich.
2. Travellers who came to Frankfurt by earthbound transport to use a non-stop or via service, now take a feeder flight to Munich and reach their destination after a transfer.
3. Some travellers who took a feeder flight to Frankfurt, now use a feeder flight to Munich.
4. Some other travellers who took a feeder flight to Frankfurt, now go to Munich by earthbound transport to use a non-stop or via service.
5. Travellers who used earthbound transport to reach Munich airport, now take a feeder flight to Munich.

It is important to note that there is no general consumer reaction due to the complex structure of the bundle of strategic supply changes which in addition causes synergetic effects. As the five possibilities show, the behaviour is always oriented to the individual situation reflecting a specific point of the elasticity curve.

The change of passengers' demand on the flights between Frankfurt and Munich is also based on their consumer reaction described by possibility 2. Information about the other kind of consumer reactions is given in figures 21 and 22 which show the changes of the catchment area of Frankfurt and Munich caused by the new destinations offered at Munich for the market segments Asia and Africa.



*Fig. 21. Market share changes at Frankfurt Airport:  
destination Asia and Africa*

For Frankfurt Airport (Figure 21) a decrease of market share up to 4% points is shown for a number of traffic zones arranged in a wider circle around the airport location, but no significant change could be measured in the vicinity of the airport. The highest losses appear in regions situated close to other airports which are now connected to Munich by feeder flights (i.e. Saarbruecken (SCN), Nuremberg (NUE), Stuttgart (STR)).

For the Munich Airport (Figure 22) a decrease of market share can be seen for the areas around the airports of Nuremberg, Hof (HOQ) and Friedrichshafen (FDH), which seems to be inconsistent with the extended schedules offered at Munich. The reason for this effect is listed as consumers' reaction possibility no. 5 where consumers change from earthbound access to feeder flights. Additional market shares for Munich are shown especially for the area of Stuttgart and the traffic zones at the border to Austria. This increase is caused by the new intercontinental destinations offered at Munich that compete with supplies at other airports.

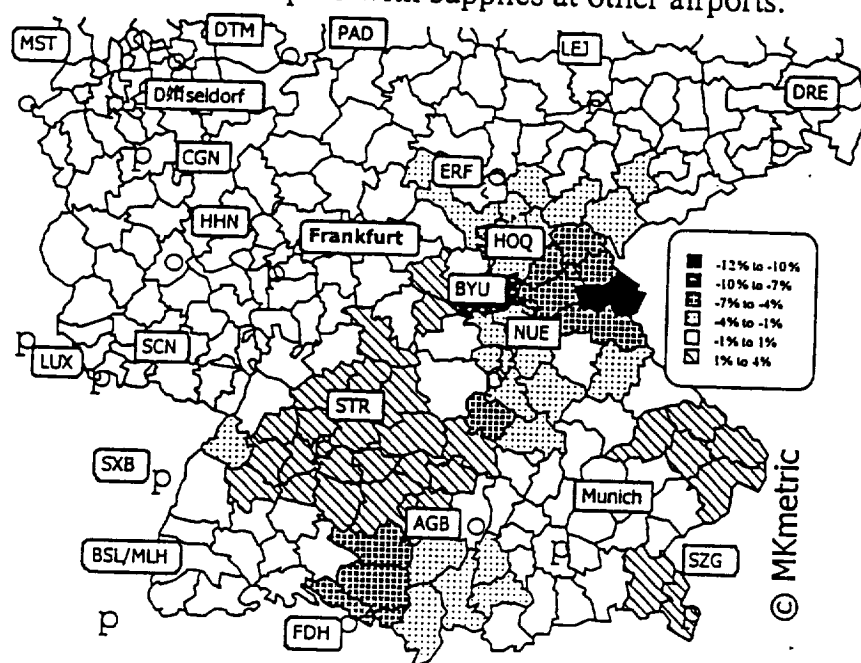


Fig. 22. Market share changes at Frankfurt Airport: destination Asia and Africa

This short analysis just sheds a light on the possibilities which are available if one goes more into detail down to the assigned air services by the different trip purposes. But the focus was not to show losses and gains at the airports, the aim was to show the variety of the consumers' behaviour in respect to supply changes and that new competitive situations arise by complex strategic scenarios which include synergetic effects which can even be measured *ex ante*. The demand elasticities in respect to any air service variable considered in the model specification (e.g. time, fare, frequency,



service attributes) allows to simulate and optimise strategies as well as to measure competition in air transport. In context with the system approach VIA (Last et al 1997) even the role of earthbound feeder systems can be considered which as we saw in the previous sections cannot be neglected.

Finally it has to be stated again that the results displayed, are aggregated concerning trip purpose and final destination. The role of the underlying access/egress infrastructure is mentioned in the consumers reaction possibilities.

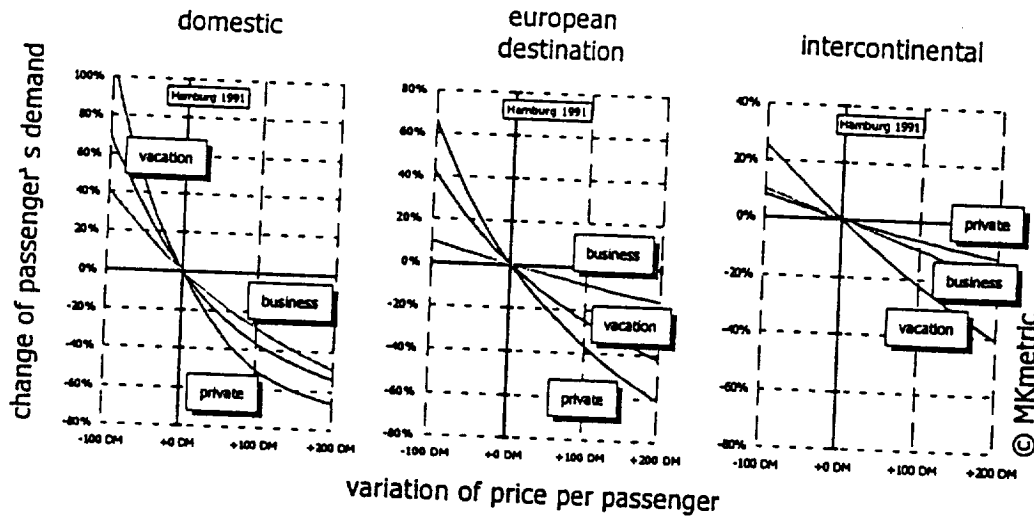
### 5.3.1. Consumer's elasticity

To demonstrate the practical relevance of the consumers elasticities the change of the market shares and travel demand of an alternative is computed in condition to an absolute change of the travel costs of this alternative whereby all other conditions remain *ceteris paribus* equal. As example the alternatives at the Hamburg airport in the year 1991 are used and displayed for three different market segments, namely domestic, European and intercontinental. The computed probabilities of the models will differ for each origin-destination pair as well as they depend on the specific trip purpose. The curvatures of elasticity are aggregated for each market segment based on the specific origin-destination (O-D) results.

The following figure 23 displays the change of passengers demand (y-axis) based on the year 1991 when tariffs change (x-axis). The zero-zero coordinates display the *status quo* at Hamburg in 1991. It can clearly be seen that the elasticity of business travellers is the smallest because changes of the tariffs have the smallest effect on their behaviour. Although increasing the tariff of domestic flights by DM 100 (~ US\$ 55) only 28% will skip the alternatives offered at Hamburg. At the same price change the share of holiday makers will decrease by 37% and the private travellers by 51%. On the domestic market segment the air services have to face a strong competition to the land based modes and in addition there are a lot of other air alternatives around so that easily instead of Hamburg the airports Hanover or Bremen can be used.

The results at a DM 100 change of the tariff for European destinations give roughly the same picture just the losses of market shares are smaller (business 7%, vacation 25%, private 38%). Surprisingly the results for intercontinental destinations are different. While the holiday makers react strongly (24%) followed by the business travellers (19%) the private travellers show the smallest effect (12%).

The strong reaction of private travellers has to be seen out of the point of view that the total length of the trip does not exceed four days and therefore the ticket takes over a major part of the total trip expenditures. This argumentation even holds if one has a look on their behaviour if the price decreases by DM 100. The gain varies from 100% on domestic and 64% on European to 25% on intercontinental destinations.



*Fig. 23. Share of travel demand depending on cost changes*

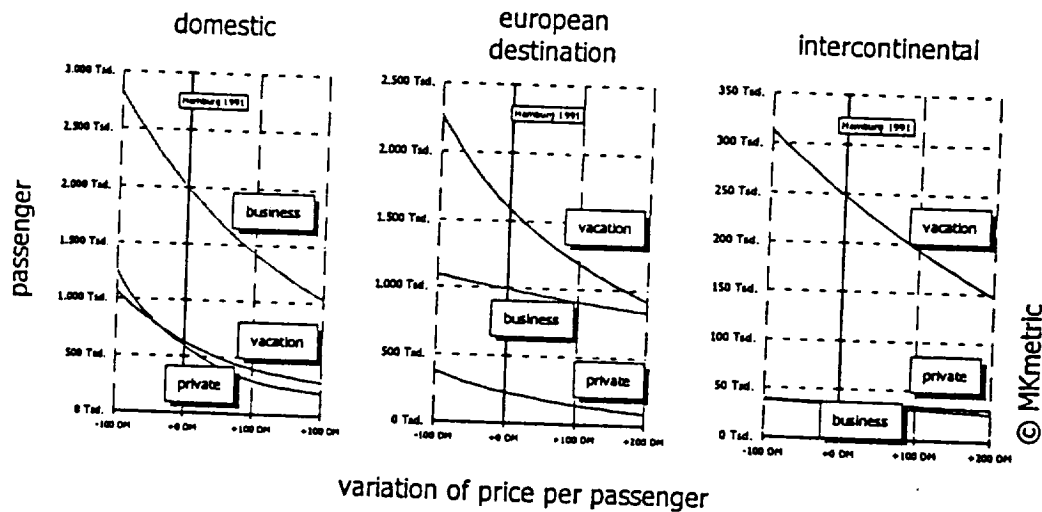
The small reaction of business travellers is consistent with the idea of the high time sensitivity of these consumers and the fact that the ticket is usually paid by the company or the visited client.

The idea of price sensitivity of holiday travellers is reflected at least in the domestic and European cases while on intercontinental trips the change of the ticket price does only slightly increase the total expenditures of the trip, so that this is of minor relevance. Anyhow the high competition on the intercontinental market is ensuring a low price level.

By the way in an air demand forecast study for Hamburg (1996) it was found that holiday trips to the same destination, same hotel etc. in the same time period offered by Hamburg tourist offices differed in price by up to DM 1.000 (~ US\$ 555) to those offered in other German cities. The major difference was just the originating airport: instead of Hamburg airport the journeys started from Frankfurt or Dusseldorf airport.

To see the effects of consumer behaviour on travel demand the following figure 24 displays the results already explained on the market share level. The absolute passenger values (y-axis) refer directly to the market shares stated above so that the interpretation of the results is obvious. One remark should be made. Some changes of the travel shares seemed to be high or low but looking at the absolute number of travellers will adjust this objective.

It should be kept in mind that the losses on the passenger side are not losses in total for the air market which will be shown later on in the next subsection in more detail (see passenger shifts). A lot of travellers just choose another air alternative - intramodality - only on short distance flights the competing high-speed trains and the car mode - multimodality - will draw market shares and of course less attractive destinations will be substituted by other ones due to the generation-distribution approach used.



*Fig. 24. Travel demand depending on cost changes*

Generally it has to be stated that changes of tariffs higher than DM 150 are not covered by the database and therefore the precision of the results is decreasing. The models have to be updated when new observations are available which catch consumer behaviour due to such large changes.

But despite this fact to the real example of an unrestricted return business trip between Hamburg and Frankfurt should be referred to because the comparison of model results and the true observations was encouraging in the sense that nor large changes of air tariffs are unusual neither the elasticities found by the models can be neglected.

For example an increase of the tariff of about DM 50 (~ US\$ 28) within a year (9.96 to 8.97) or a drop of the price by 30% and more as soon as another airline offers their service (e.g. Frankfurt – Berlin, Hamburg - Munich or Munich - Ruhr area in 1997) or the anti trust office claims monopolistic behaviour of an airline are normal if one observes the market in detail. In the light of the ongoing liberalisation, deregulation and privatisation process and the very elastic pricing strategies of airlines the question is: How can airports participate at market procedures like airlines already do for some time? Due to the enlarging capacity constraints the growing air market is facing and the huge infrastructure investments airports have to undertake the airlines and respectively the consumers have to face higher charges and / or fees. It will be a matter of time that airports will be

forced to turn to a more market oriented pricing strategy like peak & off peak pricing or the more general approach of slot trading to handle the spare capacity resources more efficient or say on the level of a real market price.

Concerning the elasticities it is referred to the example of the Frankfurt - Hamburg O-D passenger market which decreased by 4.8% from 1996 to 1997 stated by airport statistics Hamburg. Within this time period not only the air tariff increased also the service frequency on this O-D was reduced. Taking into account the average growth rate of about 7.4% in 1997 on the domestic German market the imaginable losses on this leg were 12.2% for the O-D traffic. Obviously the growth rates were induced by the additional competition of airlines on several markets in 1997 where the prices dropped significantly. Therefore considering all effects the elasticities of the models tend to be conservative. In this context the question rises: Who can benefit of consumer elasticity by applying a market oriented pricing strategy, exclusively airlines? More and more the airports view the travellers directly as clients and apply aggressive marketing strategies to increase their attractivity (free or cheap parking and overnight stay, shops, play grounds, restaurants, high-speed rail access, etc.) to enlarge their catchment area. A new pricing strategy for the aviation side would be a natural enrichment of the existing marketing tools. In addition one could use a market oriented pricing as instrument to impose a price structure to meet political constraints like environmental benchmarks.

By the way by increasing tariffs on an O-D the total demand on this leg need not necessarily decrease if one takes into account the transfer passengers, who usually pay different prices. In the case of the Hamburg - Frankfurt leg which is dominated by the origin-destination passenger market the losses on total demand were 1.8% to the demand in 1996 because the share of transfer passengers increased by ca. 2.3%.

Therefore to compute the effects on the leg level all itineraries on the total network have to be considered. Of course for each origin-destination pair as well as for each alternative serving an O&D such elasticity curvatures can be computed. Obviously it is wrong to concentrate on one airport and single services without considering the synergetic effects of a network and the competitive situation around. To face such and other complex problems like the air network or hub optimisation the airport choice models have been embedded in the system approach.

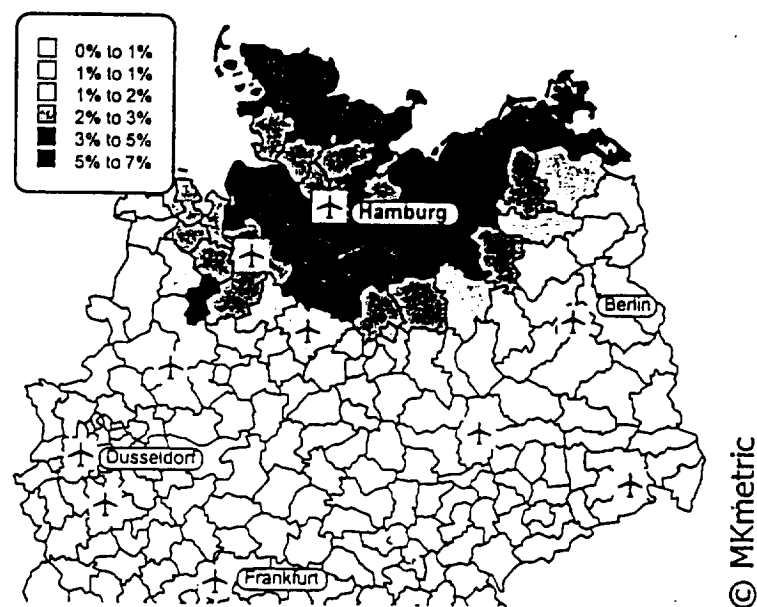
### **5.3.2. Local pricing strategy**

The last strategic scenario deals with an increase of passenger fares at an international airport which might happen in order to meet environmental benchmarks (e.g. noise, pollution) or to manage scarce resources (e.g.

parking positions, aircraft movements) efficiently. Again such an action will change the competitive situation between airports and the question arises how consumers react to the supply changes. This analysis is based on the elasticities shown in the previous subsection.

Here we assume that the international airport Hamburg charges an additional supplement — to airlines or passengers — so that the travel expenses increase by DM 50 per passenger for any flight. The resulting question will be which kind of effects can be expected? Or the other way around, if one wants to reach a certain aim / benchmark which amount of money should be demanded from whom? In both cases the focus is on the price elasticity of demand.

Figure 25 depicts the simulated market share losses for the airport Hamburg. The pattern results from passenger shifts to competing airports as well as travellers using earthbound modes (rail and road) as substitutes. The highest reductions of Hamburg's market shares can be found inside the extended area of Hamburg and in regions from where another airport (e.g. Hanover) is reachable in similar conditions, like the airport of Hamburg.



*Fig. 25. Market share losses of Hamburg Airport 1991: all destinations*

As we want to measure the competition we should have a look at the competitors. Where do consumers go to, which are the alternatives considered as substitutes, who are the winners or losers of such a scenario? Figure 26 summarises the passenger shifts between the competing alternatives.

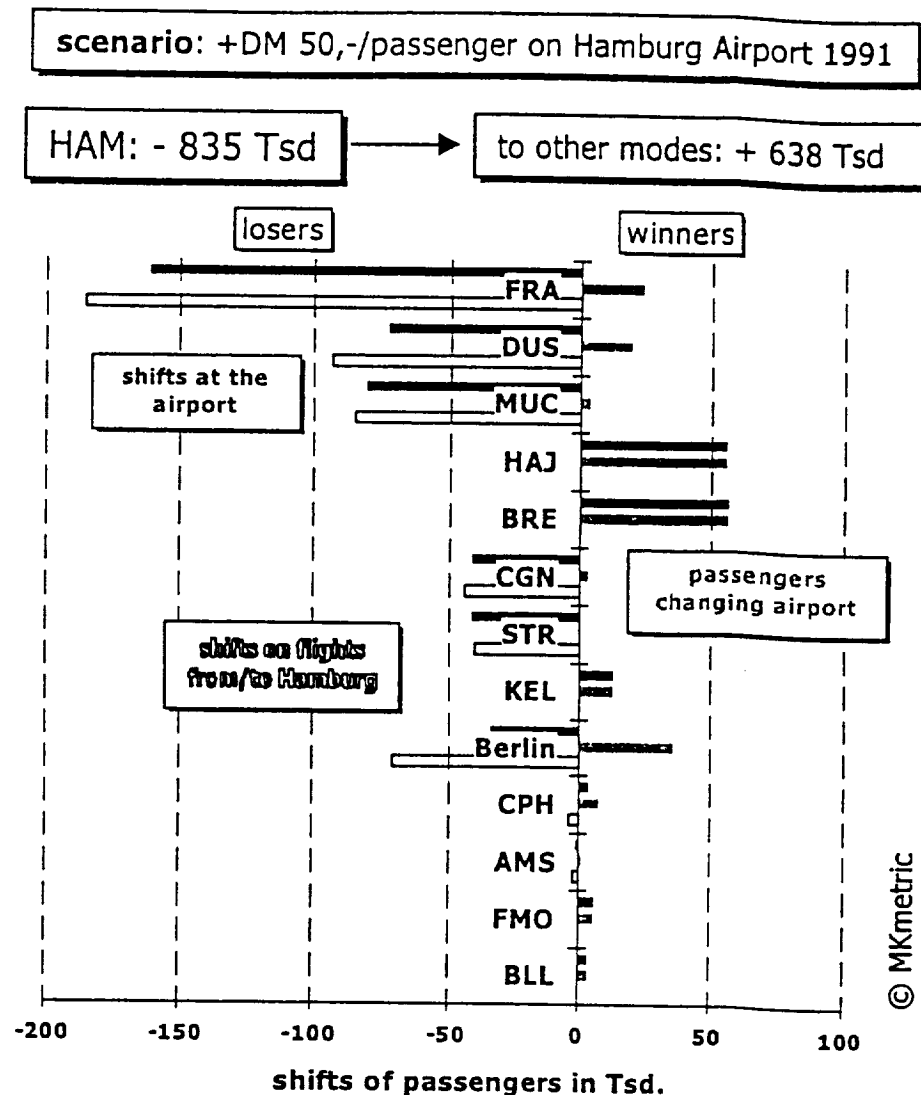


Fig. 26. Passengers shifts

As the tariff increase is relatively high for short-haul flights the major effect is a shift to earthbound modes for domestic destinations. Here air services are competing with high-speed train services which serve a city-city pair nearly as fast as airplanes.

Those airports connected with Hamburg by short-haul flights, like Frankfurt (FRA) and Dusseldorf (DUS) must be characterised as losers. But the total number of passengers on these airports decreases less than on the O-D flights because some of the travellers still reach these airports by plane just using a competitive airport like Hanover (HAJ) or Bremen (BRE). Others replace their former connecting flight (e.g. Hamburg - Frankfurt by car or rail trips to Frankfurt) and subsequently enlarge the catchment area of these airports.

Airports situated closer to Hamburg may be considered as winners in that situation, if they are not connected to Hamburg by plane and, in addition, provide a comparable number of destinations. Here, HAJ and BRE win more than 50 Tsd. passengers each, while at Kiel (KEL, in the north of Hamburg), there is only a little increase in the amount of passengers, due to the very few destinations offered there. A special kind of winner, although the number of changing passengers is quite low, is Copenhagen Airport (CPH). Despite losing passengers on the flights to and from Hamburg, the total number of people in Copenhagen increases. This result is caused by a combination of the two effects stated for Frankfurt and Hanover.

Of course one can go even more into detail by analysing the consumer structure at the Hamburg Airport and how the segments are affected by such an increase of fares. Obviously business travellers are less price sensitive than holiday makers. But having a look at the passenger figures differentiated by trip purpose, figure 27 indicates that although the number of travellers diminishes by 835 Tsd. (8%) the reaction of holiday makers is quite low - the total amount of travel expenditures is already quite high so that the extra charge does not have a tremendous influence on their decision - while trips belonging to the trip purpose private (non-business trips up to a total duration of four days) are affected strongly. Due to the high time elasticity of business travellers this consumer segment is not affected very much.

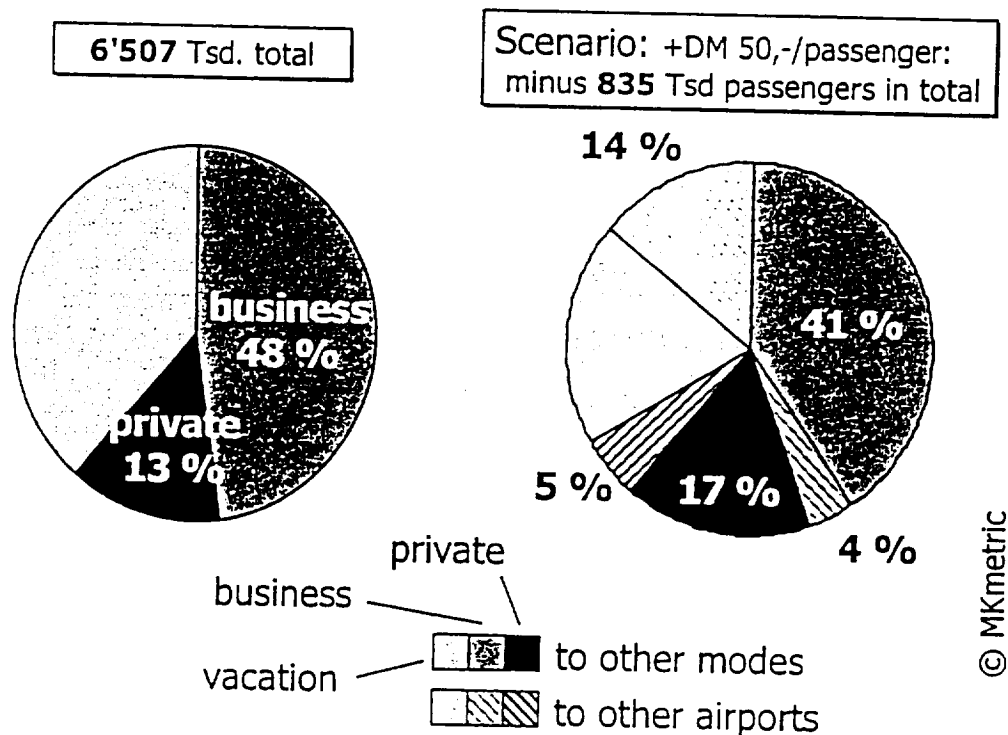
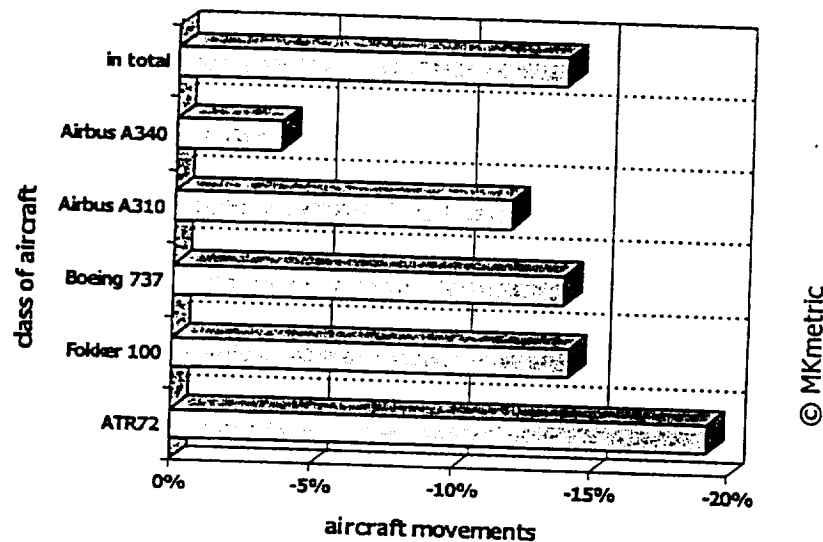


Fig. 27. Passengers at Hamburg Airport by trip purpose 1991

Again it can be stated that the elasticity of demand is dependent on the location of the traveller, the final destination and the trip purpose as indicated by the results.

Now further analyses can follow concerning the effects on different routes, the aircraft movements, the environment or finally concerning the economic impact of such an action.

When increasing airport fees at an airport, not only passenger's amount decreases, the number of aircraft movements diminishes, too as figure 28 shows. Here (DM 50 extra charge per passenger), we indicated the differences by type of aircraft. When regarding the reductions by percentage, the strongest effects are advised for the class of turbo prop (represented by ATR 72), which come into service on short hauls only. On long hauls, which are a domain of planes like the Airbus A340, the reduction of aircraft movements, caused by the lack of passengers, is almost of no account, as that DM 50 extra charge makes intercontinental flights only slightly dearer.



*Fig. 28. Change of aircraft movements Hamburg Airport 1991 (percentages)*

When simulating rising passenger charges, the changing economic situation of an airport is an important point of view. So figure 29 displays the development of aviation revenues. The actual revenues in 1991 at the airport of Hamburg were DM 180 Mill. With an amount of 6.5 Mill. passengers, aviation revenues were DM 27.61 per passenger. When rising up passenger charges *ceteris paribus*, by DM 100 (~US\$ 55), the aviation revenues will sum up to more than DM 300 Mill., although the number of passengers estimated at Hamburg decreases and there are less aircraft movements.



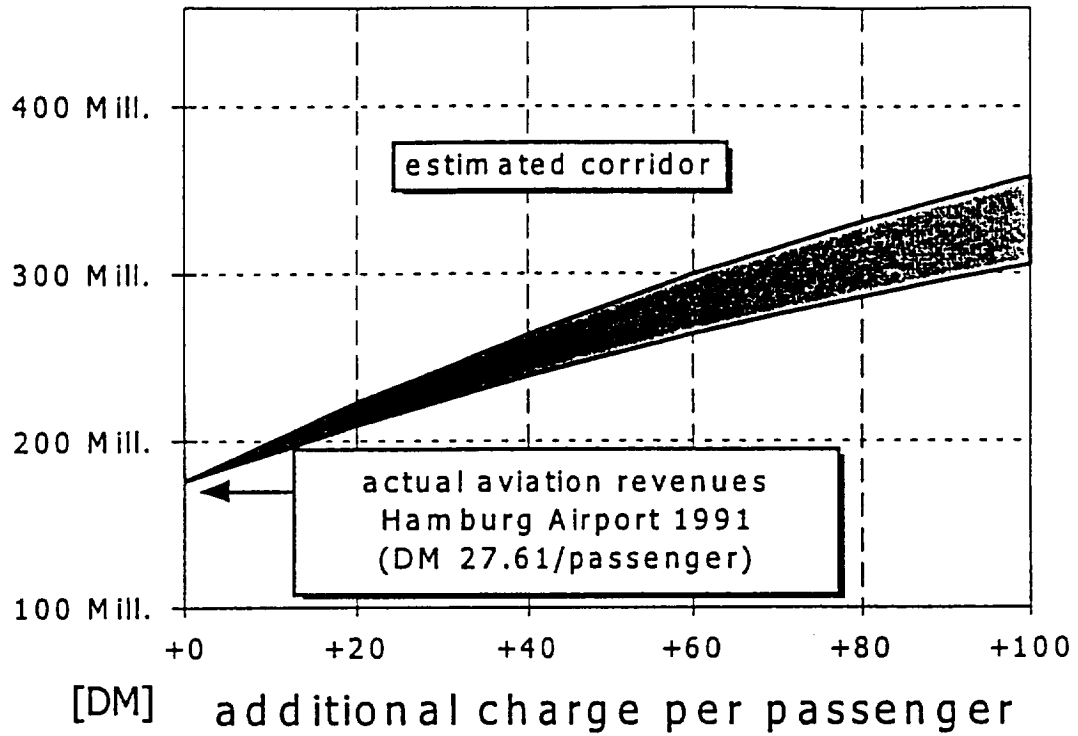


Fig. 29. Aviation revenues depending on passenger charges

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# **A Study on the Flight Service Network for Incheon International Airport to be a Successful Hub Airport in Northeast Asia**

Kwang Eui Yoo and Yeong-heok Lee<sup>1</sup>

## **ABSTRACT**

Incheon International Airport (IIA) is planned to open in about 18 months. Korean government has an ambition to make IIA a major hub airport in Northeast Asia. The most essential and required condition for an airport to be a successful hub airport in a certain region is to have more efficient flight service network than the other airports in the same region. IIA should compete with Japanese airports to be a major hub in Northeast Asia because Japanese government also has a plan to expand greatly the airport capacity in Tokyo area and Kansai airport in Osaka. It is necessary for both IIA and Korean national air carriers to compose efficient flight service network considering hub competition with Japanese major airports. As the liberalization of international air transport industry would give more marketing freedom to airlines, they would plan the flight service network and flight schedule based on market analysis instead of governmental regulations. In the economically liberalized environment, it is very required to analyze air passengers' flight choice behaviour in order to induce other carriers and passengers through IIA's attractive flight service network. Disaggregate model is more appropriate than aggregate model to analyze consumers' behaviour. The information derived from disaggregate choice model of air passengers could be utilized in devising efficient flight network and schedule plan. Value of travel time or trade off ratio between flight frequency and travel time which could be estimated from discrete choice model could be utilized for scheduling an efficient flight plan for airlines and composing efficient flight service network for IIA.

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<sup>1</sup> Both are professors at the department of Air Transportation in Hankuk Aviation University, Korea

## I . Introduction

The aviation demand in Asian Pacific region has recorded larger growth rate than in other regions during last decade. In accordance with the rapid expansion of aviation demand in Northeast Asia, the construction of Incheon International Airport(IIA) was planned to meet the growing air transport demand of Korea and to play a role as a major hub airport in Northeast Asia. They should compose efficient hub-spoke flight network centered at IIA to make it a hub airport in the area. IIA is required to compete with other big airports in the same region to become a successful hub. Especially it is inevitable to compete with Japanese airports in Tokyo and Osaka because Japanese government also has a plan to add greatly airport capacity in those big cities and Tokyo is already known as a hub in Northeast Asia.

Through the expanding open-sky policy in international air transport industry led by USA, airlines are predicted to operate to meet market needs. The national barrier will become less important than consumers' preference in the market when an international airline or an airport plans a flight service network. Therefore, the study of air passengers' behaviour in the target market should be treated as an essential base for flight service planning.

The objective of this research is to study the way how to analyze the air passengers' flight choice behaviour and apply the findings of the analysis to air carrier's(or airport's) planning of flight service network. The area to study is air transport market in Northeast Asia region. To be more concrete, we will focus on hubbing competition of IIA with major airports in Japan. As they compete by flight service network, effective flight service network should be constructed through the scientific analysis of air passengers' flight choice behaviour. In this study, we will suggest a method to apply for planning flight service network so that IIA could win a competition with Japanese airports utilizing air passengers' choice model.

There are several previous researches to utilize passengers' flight choice models in air transport planning area. Kanafani and Ghobria utilized air passengers' route choice model for their research concerning hub pricing of airport[7]. Benchemam also utilized discrete choice model to study air passengers' airport choice behaviour in UK[4]. Alamdari and Black studied passengers' choice of airline with logit models[1].

Following this introduction, section 2 is to review the air transport market in Korea and Japan. Section 3 will discuss hubbing strategies in air transport industry. Section 4 will introduce the method of empirical research and section 5 will be dedicated to main discussion of this study and section 6 is the concluding remarks of the study.

## II . Air Transport Industry in Korea and Japan

This section will introduce the shape of air transport industry in Korea and Japan. However, this study does not introduce detailed information because it is not very necessary for the purpose of this study. The following sub-sections are to review it roughly, only mentioning the basic information related to this research.

### 2.1 The Policy for Air Transport Industry

The policy for domestic air transport in Korea has been somewhat led by government regulation. Now, there are two scheduled airlines operating as private corporation; Korean Airlines(KAL) and Asiana Airlines(AAR). Korean government which wants to introduce deregulation to all industry has changed regulatory form of air transport industry in order to make it greatly deregulated. It can be expected that domestic air transport is going to be operated without governmental regulation in near future. For international air transport, Korean government is seeking different policy case by case. As they accept the suggestion of "open sky" from USA, the international air transport between US and Korea is operated in economically liberalized environment. Airlines in this market can decide air fare, service route and service frequency without government intervention. However, the bilateral air service agreements with other countries except USA are more restrictive. They usually regulate service route and frequency.

Japanese policy for air transport industry is a little more restrictive than that of Korea. Japanese government would like to lead air transport industry to the direction where they intend to drive. For international air transport, Japanese government also takes more conservative attitude than Korea, since they feel Japanese airlines are not so competitive, caused mainly by high cost. They want to keep on regulating air fare even though the degree of regulation is going to be less severe. However, Japanese government is considering the expansion of the routes of multiple designation. In general, they also try to adopt themselves to new wave of international deregulation of the industry.

### 2.2 Capacities of Major Airlines and Airports in the Market

There are several big scheduled airlines in Korea and Japan. In the aspect of capacity, JAL ranked the first place beyond compare and ANA ranked the second place by a little more capacity than KAL which ranked the third place. AAR ranked the fourth and JAS ranked the fifth (refer to table-1).

Table 1. Major Airlines' Capacity in Korea and Japan (1997)

Rank	Airline	Aircraft owned	RPM(millions)	World rank
1	JAL(Japan)	143	43,357.4	6
2	ANA(Japan)	137	26,629.4	14
3	KAL(Korea)	119	20,991.9	18
4	AAR(Korea)	45	8,026.5	39
5	JAS(Japan)	88	6,950.9	-

source: "Major Airlines Profiles", Aviation week & space technology, Jan. 1998

There are three major international airports in the market; New Tokyo International Airport in Narita Tokyo, Kansai International Airport in Osaka, and Kimpo International Airport in Seoul. New Tokyo International Airport has one runway and has a plan to add two more runways. Kansai International Airport is also operating one runway and has a plan to add two more runways. Kimpo International Airport has two runways. However, in January 2001, all of the international flights will move to new Incheon International Airport which will have one runway at the opening date and another one in six months. Eventually, Incheon International Airport will be operated with four runways when they finish final stage of construction.

The air passenger demand in Japan is concentrated in Tokyo area and Osaka area. New Tokyo International Airport and Kansai International Airport handled a major portion of international air passengers in Japan. In Korea, Kimpo International Airport handles almost all of the international air passengers. Table-2 shows the international traffic demand on these three airports.

Table 2. International Passenger Demand at Each Airport(1996)

City	Airport	International Passengers (thousands)
Tokyo	New Tokyo Airport	23,372
Seoul	Kimpo Airport	21,271
Osaka	Kansai Airport	8,578

source: 1. "Aviation shown by number(数字でみる航空)", Japanese Civil Aviation Bureau, 1997

2. "Aviation Statistics", Korea Aviation Development Association, 1997

### III. Hubbing Strategy in Air Transport Industry

#### 3.1 Introduction - Justification of Hub-Spoke Network System

With the deregulation of air transport industry, airlines have altered their route structure to utilize their resources more efficiently and the hub and spoke flight network is proved to be effective. Hubbing occurs when airlines concentrate flights at a few airports which they use as collection-distribution centers for their passengers. Through hubbing, an airline could increase the number of connecting cities and flight frequencies with limited resources, which can be explained by fig.1.

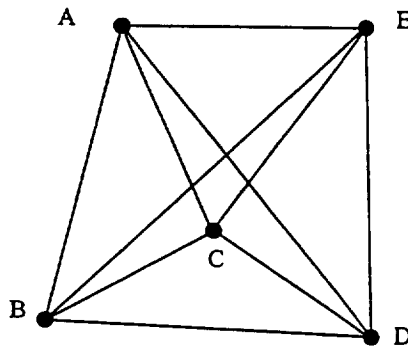


fig.1(a) Flight Service Network  
with direct Connection

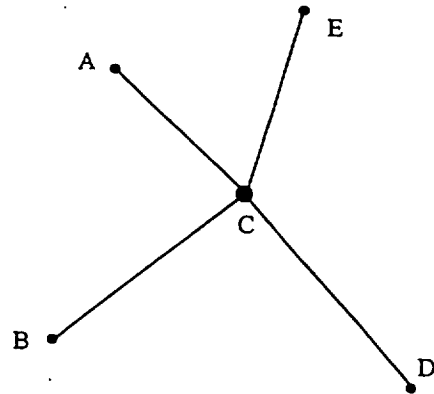


fig.1(b) Flight Service Network  
utilizing Hub-and-Spoke system

Fig.1(a) is to serve five cities with complete connection, by direct service only. As shown at fig.1(a), ten ( ${}_5C_2 = 10$ ) routes are required to supply complete connection with direct service for these five cities. Fig.1(b) is utilizing hub-and-spoke system, and it can be seen that only four routes are required to connect five cities by way of the hub city "C". If the city "C" is a big city generating large traffic demand, the flight frequency between "C" and other cities could be greater than that of between small cities. Therefore, the passengers, for example, who want to travel between "A" and "D", have to transfer at "C", and this will enforce more travel time to passenger while the passenger can enjoy convenience by more flight frequency with hub-and-spoke flight service network. The air fare for connection flight usually cheaper than that of direct flight because airlines can reduce unit cost through high load factor. In many cases, since the route between hub city and a certain spoke city is for the purpose of transportation between hub and that spoke city, it may be considered as an additional revenue for the airline that earned



from the passengers who travel between one spoke city and another spoke city by way of hub city. This will result in low air fare for the passengers who use connection flights. Therefore, the consequences for the passengers using hub-and-spoke system are the benefits from trading off longer journey times for more frequent flights, if necessary, and, on certain routes, the benefits from using cheaper flights.

Even though it is normally accepted that travelers consider flight frequency, travel time and fare in their decision making procedure of transport choice, it has been proved that high frequency is usually more attractive to passenger than short travel time. In a competitive market, frequency seems to be a key variable and the S-curve relationship between frequency and market share is often cited.

Since hub-and-spoke network systems are utilized in major continents in the world, multiple hub system serving between continents has been also developed(refer to fig.2).

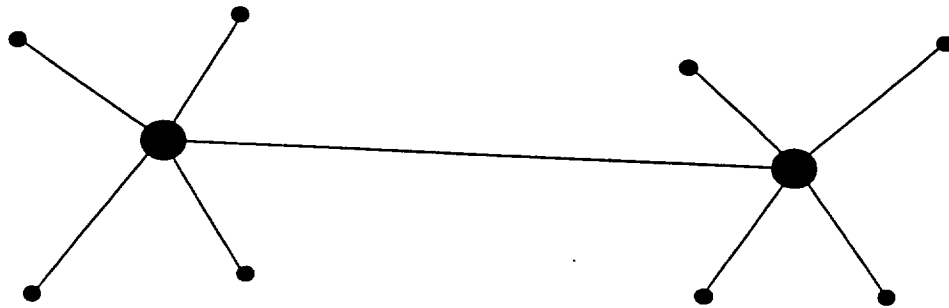


Fig.2 Multiple Hub System

### 3.2 Two Kinds of Hub

As Doganis and Dennis(1989) proposed, it is reasonable to classify hubbing function of airports by two main kinds of hub; hourglass hub and hinterland hub (refer to fig. 3)[5]. As shown by fig. 3(a), through an hourglass hub, flights operate from one region to points in the opposite direction. Through a hinterland hub, short haul flights feed connecting traffic to the longer trunk routes. An hourglass hub usually only caters for connections in two directions, outbound and return. However, a hinterland hub serves as a multi-directional distribution center for air travel to and from its surrounding catchment area.



fig.3(a) Hourglass Hub

fig.3(b) Hinterland Hub

#### IV. Research Method

##### 4.1 Introduction

It is essential to study air passengers' behaviour for the planning of flight service network in the greatly deregulated air transport market. Disaggregate model is more appropriate than aggregate model in analyzing consumers' behaviour. This section will try to find the method how to apply the information derived from disaggregate choice models to flight service network planning.

By traditional economic assumption, commodities are finely divisible with a change in price having an effect on the quantity of the goods demanded. However, this assumption does not hold for some commodities, transport choice being one of them. For such commodities, a change in price may result in zero consumption or unaffected consumption. When commodities are not finely divisible, marginal adjustments of consumption are not feasible consequences. Thus the individual behaviour of consuming discrete commodities is better represented by an individual choice function.

##### 4.2 Theory of Individual Choice Behaviour

It is assumed that the individual attempts to choose from the range of alternatives the option that maximizes overall utility, when the hypothesis of utility maximization is used as the decision rule of discrete choice. Individual  $k$  will select alternative  $i$  among a set of  $J$  alternatives if

$$U_{ik} > U_{jk} \quad (i \neq j, j=1, 2, 3, \dots, J) \quad (1)$$

However, in repeated choice experiments, individuals have been observed not to select the same alternatives in the same situation, and different decision makers have selected different alternatives in the same situation with the same alternatives. This led to the development of probabilistic choice theory which attempts to explain these behavioral inconsistencies[3]. This behavioral inconsistencies could be explained by random utility theory. In this random utility approach, the observed inconsistencies in choice behaviour are considered to be a result of observational deficiencies on the part of the analyst. The individual is assumed to select the alternative with the highest utility. However, the utilities are not known to the observer with certainty, and hence treated as random variables. Manski (1973) identified four sources of the randomness of the utilities,

- unobserved attributes
- unobserved taste variations
- measurement errors and imperfect information
- instrumental(or proxy) variables

With random utility approach, the utility of the  $i$ th alternative for the  $k$ th individual can be partitioned into two components,

$$U_{ik} = V_{ik} + E_{ik} \quad (2)$$

where  $V_{ik}$  represents the observable component, which also can be expressed as the systematic component or representative utility.  
 $E_{ik}$  is the unobservable component or random component.

It is assumed that the systematic component is the part of utility contributed by attributes that can be observed by the analyst. For the random component, the sources of randomness are those stated in the above paragraph. Since, in consuming commodities, individuals attain utilities by consuming bundles of attributes which define level of service, a relationship between utility and level of service can be defined, so that the observable component of total utility in equation(2) can be expressed as follows if a linear-in-parameters is assumed.

$$V_{ik} = a_0 + a_1X_1 + a_2X_2 + \dots + a_nX_n \quad (3)$$

where,  $V_{ik}$  = systematic component of utility of option  $i$   
for individual  $k$

$a_0, \dots, a_n$  = coefficients

$X_1, \dots, X_n$  = attributes of option  $i$

The coefficients ( $a_0, a_1, \dots, a_n$ ) are assumed to be the same for all members of the population in equation (3). If different socio-economic groups are believed to have entirely distinct coefficients, then it is possible to develop an entirely distinct model for each subgroup. This is termed as market segmentation. However, socio-economic characteristics are often included in the model using an appropriate specification. In such a case the utility function can be expressed as follows;

$$U_{ik} = U(Z_i, S_k) \quad (4)$$

where,  $Z_i$  = a vector of attributes of alternative  $i$

$S_k$  = a vector of socio-economic characteristics of individual  $k$

#### 4.3 Choice Model of Random Utility

This subsection will introduce the basic theory of the random utility model, as the random utility approach is more consistent with economic theory. By combining probabilistic choice theory and random utility theory, the following equations are obtained;

$$P_{ik} = \text{Prob.} [ U_{ik} > U_{jk} \quad i \neq j, j = 1, 2, \dots, J ] \quad (5)$$

$$P_{ik} = \text{Prob.} [ V_{ik} + E_{ik} > V_{jk} + E_{jk} \quad i \neq j, j = 1, 2, \dots, J ] \quad (6)$$

$$P_{ik} = \text{Prob.} [ E_{ik} - E_{jk} > V_{jk} - V_{ik} \quad i \neq j, j = 1, 2, \dots, J ] \quad (7)$$

where,  $P_{ik}$  is the probability of selecting alternative  $i$  for individual  $k$  facing a set of  $J$  alternatives.

It is important to stress that  $V_{ik}$  and  $V_{jk}$  are functions of service attributes and are assumed to be deterministic. The terms  $E_{ik}$  and  $E_{jk}$  may also be functions, but they are random from the observational perspective of the analyst. It is usually assumed that the means of the random variable  $E$ 's are zero, and any non zero means of  $E$ 's are 'absorbed' into the systematic

component of the utility function, unless noted otherwise.

One of the most difficult arguments of random utility theory is defining a reasonable functional form for  $V$ . Ben-Akiva and Lerman proposed two criteria for selecting functional form; (1) the function to reflect how the various attributes in the alternative set influence utility (2) the function that has convenient computational properties that make it easy to estimate their unknown coefficients[3]. In most case, functions of linear-in-parameters are chosen. As for the functional form for the distribution of random component  $E$ , different assumptions regarding the distribution of  $E$ , lead to different choice models being developed. Although several models for the multinomial choice situation have been developed, multinomial logit (MNL) is the most widely used multinomial choice model.

#### 4.4 Application of Stated Preference Techniques

Often it is not easy to calibrate an efficient discrete choice model with revealed preference data because there is not sufficient variation of all variables of interest, and there are also often strong correlation between variables or between variables and other invisible factors. Stated Preference(SP) techniques which allow the researcher to experiment, can offer a solution to these problems. With clearly defined attributes and attribute levels, SP experiments can give researchers the chance to have sufficient variation of variables of interest, and an orthogonal design which ensures that the attributes presented to respondents are varied independently from one another, avoids multi-collinearity between attributes.

##### 4.4.1 Introduction to Stated Preference Techniques

SP methods which were originally developed in marketing research in the early 1970s have been applied in the empirical analysis of transport-related choice behaviour since 1979. Though these techniques were severely discredited at their beginning, by the end of the 1980s, they were perceived by many researchers to offer a real chance to solve the problem related to transport demand modeling.

Kroes and Sheldon (1988) described SP methods in transport research as a family of techniques which use individual respondents' statements about their preferences in a set of transport options to estimate utility functions[9]. The options are typical descriptions of transport situations or contexts constructed by the researcher. Generally, SP techniques can be

defined as all the approaches which use people's statements of how they would respond to hypothetical situations.

#### 4.4.2 Advantages of SP Techniques

Transport planners need to know the likely effect of any planning strategy they consider. However, the traditional methods using revealed preference data cannot provide good quality information on travel demand and travel behaviour mainly because there is insufficient variation in the variables of interest to produce statistically significant models, and further, such variables are often strongly correlated. Moreover, revealed preference methods cannot be used to evaluate demand under conditions which do not yet exist. SP techniques, however, allow the researcher to experiment the consumer behaviour under various conditions, offering an effective solution to such problems. The advantages of SP techniques over revealed preference (RP) methods are summarized as follows[11]:

(1) RP : Observations may not vary sufficiently for the construction of an accurate statistical model and the variables may also be correlated making it difficult to estimate model parameters reflecting the proper trade-off ratios.

SP : SP techniques can ensure data of sufficient quality to construct a good statistical model because the researcher can control the choices offered to respondents.

(2) RP : The observed behaviour may reflect factors which are not of interest to the policy maker. In addition, the effects of the variables that are of interest may be "swamped" by these other factors. This is a particular problem with "secondary" qualitative variables.

SP : Due to the control available to the researcher, the effects of variables of interest can be isolated from the effects of other factors.

(3) RP : There is no information on how people will respond in situations where a policy is completely new.

SP : Where a policy is completely new, so that no RP data is available, stated preference techniques may represent the only practical basis for evaluation and forecasting.

(4) RP : To obtain adequate observations of behaviour, very large and therefore very expensive surveys may have to be carried out.

SP : Since each stated preference interview produces multiple observations per individual,

efficient statistical models can be developed from much smaller sample sizes.

## V. A method on IIA's Strategic Flight Service Network Planning to Win Hub Competition in Northeast Asia

This research reviewed air transport industry and introduced the hubbing strategies in the industry and discrete choice modeling. In this section, we will discuss how to utilize the information which could be derived from discrete choice model for IIA's strategic flight service network planning to make it successful hub airport in Northeast Asia.

### 5.1 Information derived from Discrete Choice Model to be Utilized for Flight Service Network Planning

This paper will research the method to utilize the information derived from the analysis of air passengers' flight choice behaviour for flight service network planning of IIA. Discrete choice model is useful to understand passengers' choice behaviour. Under the assumption that some utility functions concerning air passengers' flight choice have been calibrated, the methods to utilize the information derived from the models to IIA flight service network planning will be presented in this section.

Through the previous studies in the industry, it has been identified that flight frequency, air fare, and travel time are the major attributes to air passengers' flight choice behaviour[12]. If a discrete choice model is calibrated using these three attributes and equation (3) of this study, the results may be presented as follows;

$$V = a_0 + a_c \text{ FARE} + a_t \text{ TIME} + a_f \text{ FREQUENCY} \quad (8)$$

Even though the magnitude of individual coefficient of equation (8) is important to estimate the weight of each variable considered in consumers' choice behaviour, this study would try to utilize relative importance of pair of variables, which can be estimated as the ratio of any two coefficients. The reasons to utilize relative importance of variables are as follows: (i) The passengers' flight choice or route choice is decided comparing each variable. That is to say, relative importance of variables becomes significant factor when he/she decides to choose an air trip anyway. (ii) Especially, the model coefficients estimated from SP data are not proved appropriate to be utilized as absolute value. Instead, the SP model is useful for seeing the relative importance which can be estimated by comparing the absolute value of coefficients[11].

There can be three ratios estimated by comparing any two variables with each other if a model is composed of three variables; air fare, travel time and flight frequency. The three ratios and their significance could be explained as follows, utilizing the quotation of the coefficients of equation (8):

(i) RATIO-1;  $a_t/a_c$

*where;  $a_t$  is the coefficient of travel time variable*

*$a_c$  is the coefficient of travel cost(air fare) variable*

(ii) RATIO-2;  $a_f/a_c$

*where;  $a_f$  is the coefficient of flight frequency variable*

*$a_c$  is the coefficient of travel cost(air fare) variable*

(iii) RATIO-3;  $a_f/a_t$

*where;  $a_f$  is the coefficient of flight frequency variable*

*$a_t$  is the coefficient of travel time variable*

RATIO-1 is the ratio between travel time value and travel cost value. This ratio is the most frequently utilized relative importance in transport studies, which is usually mentioned as value of travel time (VOT). The relative importance of flight frequency to air fare can be calculated by RATIO-2. RATIO-3 is the ratio between the coefficients of flight frequency variable and that of the journey time variable. This ratio is usually considered as a trade off between service frequency and travel time and can be utilized when they consider the choice between direct route system and hub-and-spoke system.

## 5.2 Methods to apply the Information derived to IIA's hubbing strategies

### 5.2.1 Application to Hinterland Hub Strategies

It is essential factor to have plenty of short-haul flights in catchment area in order to be successful hinterland hub. In addition, they should try to reduce transfer time required to change aircraft for the connection between short-haul and long-haul flights. IIA should try to increase the flight frequency considering the competition with Narita and Kansai Airports. Since the major airlines in Korea have much less capacity than Japanese major airlines to have enough flights to compete with, it is desirable for Korean airlines to utilize the alliance with Chinese



airlines and Japanese regional airlines. With limited capacity, Korean airlines and IIA airport operator should try to supply more efficient flight service to make IIA a successful Northeastern Asia hub airport. In order to achieve such an object, this study suggests that the ratios of coefficients of discrete choice model can be utilized as follows.

They can utilize RATIO-1 to set air fare and to decide aircraft type to introduce. It is basic to introduce cheap and slow aircraft for the routes which reveals low VOT (value of RATIO-1) and to introduce expensive and higher speed aircraft for the routes which reveals high value of VOT. It is required to consider RATIO-2 in order to compromise the level of frequency and air fare. For the routes which have higher value of RATIO-2, they should try to increase flight frequency suffering low load factor. Low load factor may lead to high price inevitably if airlines seek to recover the operation cost. On the other hand, for the routes which have lower value of RATIO-2, it is effective to reduce flight frequency, which could result in higher load factor and lower air fare.

It is a normal practice that the routes which have large portion of business passengers would have higher value of RATIO-2 than the routes mainly composed of leisure passengers. If any routes are operated for mainly leisure passengers with small amount of demand, and if there is significant local traffic between cities near each other, then combining destinations on one or more spoke can be effective (refer to fig.4). In the case of which RATIO-1 is very small, this kind of routing strategy is desirable.

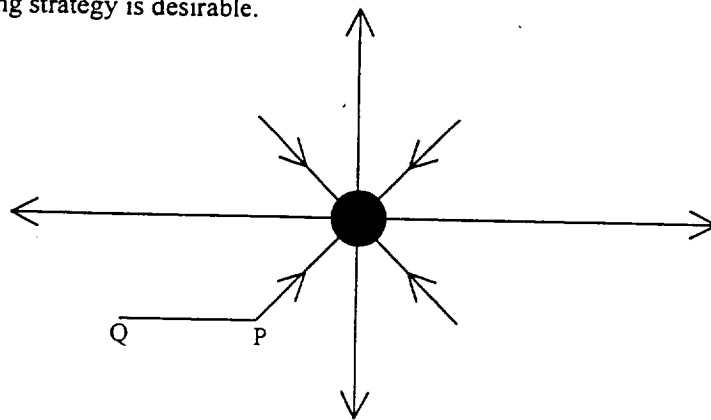


fig.4 Hub and Combining Spokes Network  
( Cities "P" and "Q" are combined spoke in the figure)

It would cost some expenses to improve operational standard to reduce connecting time on hub airport. The airline and airport operator should decide the level of cost to invest in order to reduce transfer time and they should set the level of air fare to recover the invested cost. It is useful to utilize RATIO-1 to optimize these two variables; travel time and travel cost. However, for the passengers originating from the cities where direct connections to long-distance major

cities are impossible or inconvenient, it may be desirable to introduce low fare and high frequency service utilizing sixth freedom transportation to strength hubbing concept of IIA.

### 5.2.2 Application to Long-haul Flight Service Network Planning of IIA

We consider the long-haul flights as flights to serve inter-continents routes and there are relatively large demand between Korea and North America/Europe. However, the European routes are significantly regulated by bilateral air service agreements and the demand to Europe is far less than that of USA. For this reason, this study would discuss the flight network planning strategies on the routes to North America only as long-haul flights.

Because of the inferiority in the aspect of airline capacity as well as the magnitude of demand, Korean airlines should utilize effective flight schedule and efficient alliance with the major airlines in US. Fig.5 shows the current flight service between Seoul and major cities in North America. IIA and Korean airlines could consider to change current network to new system as shown on fig.6.

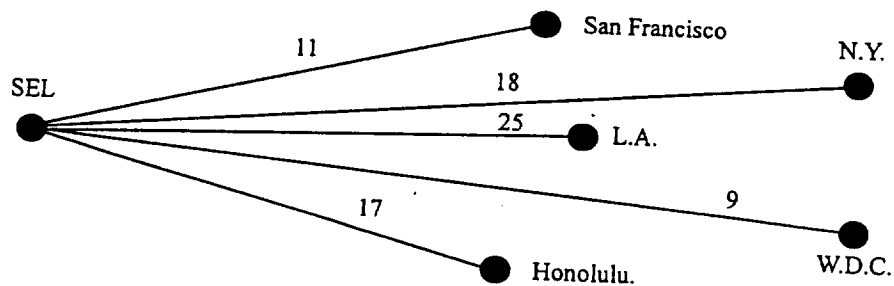


fig.5 Long-haul flights between Seoul and Major Cities in North America

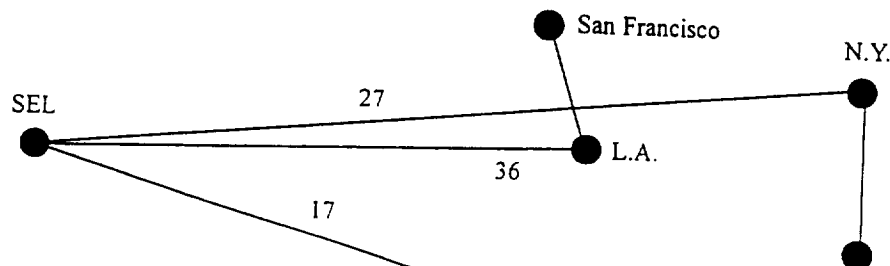


fig.6 An Example of Revised Long-haul flights

The new system is the one which impose hubbing concept. The old one which has direct connection to many cities with low frequency may be suitable for the leisure traveler and for cargo. However, such low frequency services do not offer the flexibility required by business community. The new system is to concentrate on high frequency services on the dense routes. For the other cities, connections are provided either by change of gauge equipment or allied partner airline's own local service. However, no one can calculate that the new system is better than old one for the airlines' or air passengers' welfare. It is necessary to estimate RATIOS defined in this study, and apply it for the decision making.

The discrete choice models should be calibrated for individual route separately. If the RATIOS estimated from discrete choice model of each route reveal that passengers of each route prefer evenly direct flight with scarce frequency of flight, which means high value of  $RATIO-1$  and low value of  $RATIO-2$ , the old system is more appropriate than new one. However, if the RATIOS estimated from discrete choice model of each route are significantly different or they show that high frequency with longer travel time preferred, then it is justified to introduce new system.

To introduce new system, they estimate RATIOS from discrete models of each route, for example, route to Los Angeles, and route to San Francisco. They need to concentrate the flights on the route of the higher value of  $RATIO-1$  which is selected as trunk route. The reason why they should utilize  $RATIO-1$  is that  $RATIO-1$  is the most seriously damaged one by intermediate stop. That is to say, the passengers who have higher VOT should be provided with direct service.

In addition, Korean airlines could utilize codesharing or other alliance techniques with American airlines to compose efficient flight network. Especially, the connection flight between foreign hub and spoke cities in USA should be operated by some of US airlines which allied with Korean airlines. Therefore, an airline which has scheduling power on foreign hub airport should be pointed as alliance partner. The transfer time between Trans-Pacific long-haul flights and short-haul flights connecting to some cities in US should be considered utilizing  $RATIO-1$ . This is because there is considerable competition with direct flights.

### 5.2.3 Application to Hourglass Hubbing Strategies

It is reasonable in the aspect of geographical position for IIA to take a role acting as an hourglass hub to connect the air passengers traveling between Southeast Asian Cities and Cities in the West Coast of USA. Actually, significant number of passengers traveling the cities of these regions are transferred at Kimpo International Airport. This traffic could be handled as the sixth freedom air transport and low fare could be applied. Anyway, to set the air fare and flight frequency RATIOS should be utilized. To compete with direct flights between Southeast Asian Cities and West Coast Cities in USA, IIA should offer low fare and high frequency which can offset the negative effect caused by longer travel time. RATIO-1 would be effective in setting air fare and RATIO-3 would be effective in setting the level of flight frequency.

The results found through the discussions of section 5.2 could be summarized like table-3.

Table 3. Summary of IIA's Efficient services Network Strategies

	Major factors of competition	Applied RATIOS
Hinterland Hubbing Strategies	Plenty of short-haul flights Minimum Connecting Time Introducing efficient aircraft type	RATIO-1 : to set air fare and aircraft type RATIO-2 : to compromise the level of frequency and air fare
Long-haul flight Service network Strategies	Integration of long-haul flights to concentrate on competitive routes	RATIO-1, RATIO-2: to select the routes which IIA concentrates on
Hourglass Hubbing Strategies	Increasing 6th freedom transport Low fare and high frequency service	RATIO-1 : to set airfare RATIO-3 : to set the level of service frequency

## VI. Concluding Remark

With the trend towards liberalization in air transport industry, air passengers will have more options for their travel. In a more flexible planning environment, air transport system planners, airport operators and airline operators will need to know the consumer's preference. IIA which has an ambition to be a hub airport in Northeast Asia should study the consumer's behaviour and utilize the results for flight service network planning. Discrete choice models would be useful for analyzing air passengers' flight choice behaviour. Section 5 of this study introduced several ways to apply the information derived from air passengers for IIA's hubbing strategy.

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# AIRFREIGHT FROM A PROCESS CONCEPT

Prabal ACHARJEE  
Kenth LUMSDEN

Department of Transportation and Logistics  
Chalmers University of Technology  
S-412 96 GÖTEBORG, Sweden  
Fax: +46 31 772 1337  
Phone: +46 31 772 1326  
E-mail: [prabal@mot.chalmers.se](mailto:prabal@mot.chalmers.se)

Phone: +46 31 772 1345  
E-mail: [krl@mot.chalmers.se](mailto:krl@mot.chalmers.se)

## ABSTRACT

Airfreight has gained a significant rise in the market as the need for fast and efficient transportation has increased over the years. Airfreight is transported either through pure freighters and trucks or through the belly of the passenger planes. The process of transporting freight through the belly is rigid through several factors like short turnaround time, priority issues, ramp congestion at peak hours, aircraft types etc. Belly's flexibility lies in the frequency of the flights to make it theoretically possible to deliver the goods on the same day. Pure freighters are not constrained by as many of the hindering factors as does the belly but not similarly flexible to manage deliveries on the same day. The strategy of the integrators is purely to deliver the goods 'overnight' and thus they are rigid in their services and processes. This paper analyzes the airport processes related to belly-airfreight and also the possibility of utilizing the belly more efficiently. The paper also investigates if a more efficient utilization of the belly at the daytime can generate a new concept of processing airfreight by achieving a more significant share of the market. The paper is empirically based on qualitative and quantitative data generated from the airport process operators.

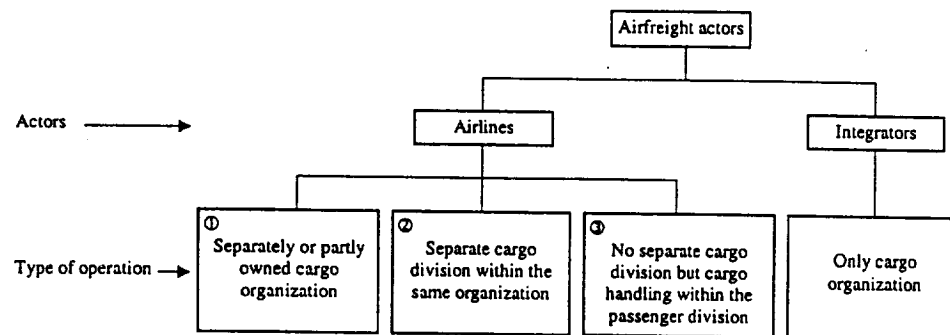
## 1 INTRODUCTION

Airfreight is normally defined as freight with high-speed delivery. Goods originated from the shipper gets the fastest carriage (as airfreight) on its way to the final receiver. Need for fast and secured transportation has considerably increased under the last decades as a result of new layouts in industrial activities, for example, customer-order driven production and centralized warehousing (Lumsden, 1998). The airfreight market is increasing by 12-15% every year. In Sweden, for instance, export by air has been increased by 18-20% under 1997 (Transport och Hantering). In spite of the fast growth of the airfreight market, there is a lot of conservatism in

the branch. Although the growth of airfreight has been more in compare to the growth of the passengers, airfreight is still considered as a by-product in the line-based traffic (Dahllöf 1997). Earlier, airfreight was never forecasted to be an industry. A proof to this argument is the architecture of the airports in general, which is not very friendly when it concerns cargo handling. Faster and secured delivery is a prerequisite for the existence in the market for many actors. Often airfreight is the only realistic alternative.

## 1.1 Airfreight actors

Airfreight can be transported in different ways - via pure freighter, via belly of the passenger planes or via trucks. The customers do not need to know which of the three ways the goods are transported by. What they are interested to know is that the goods are delivered fast and on time as promised.



**Figure 1: Airfreight actors**

The airfreight actors can be divided into two kinds. The traditional actors i.e. the airlines and the latterly emerged integrators. The airlines have in principle three different strategies in their cargo operations. Cargo could be:

1. a wholly (or partly) owned separate organization within the same brand name; or
2. a separate division within the airline; or
3. a not separated division in the airlines.

The *first type* of cargo organization is generally independent or tends to be independent of the passenger unit for their services. They generally plan their operations in such a way so that they can utilize their own resources as much as possible. They buy specific services from the passenger unit. The *second type* of cargo organization do not own resources themselves and pays to the parent company price for utilizing its resources. Cargo activities in the *third type* do not constrain themselves in any organizational boundary. There are companies that do not have any separate division for cargo. They set price for the freight and whatever is shipped is considered as a contribution to the business. Airfreight is a by-product for these companies and considered as 'better than nothing'.



The integrators, on the other hand, have *integrated freight flow* all over the chain. Their strategy is to deliver the goods overnight. They own all the assets (e.g. different vehicles, information system, etc.) all the way from the shipper to the final receiver. Consequently, they have a good control over the flow and can effectively (but in a rigid way) deliver the goods. Their quality service has made it possible to have a continual increment in their market share. Although their core business was to make door-to-door delivery of small packages, they are continuously expanding their operations with additional services of shipping bigger volume of freight.

## **1.2 The importance of belly capacity**

The most economical way to transport the airfreight is through the empty belly of the regular passenger aircraft in the line-based traffic. This is obvious if seen from the transport provider's point of view. The cost is then minimum and the income is maximum. There is also an advantage of the belly utilization and that is - the flights have a very good frequency. The customer service (for freight) could be increased if the belly is used smartly. The problem although with the passenger planes is that these are designed to transport people, not freight. Here, a priority list is maintained where freight, unfortunately, is the last to enter an aircraft. Moreover, there are other factors that hinder a better belly utilization, e.g. — departure time, type of aircraft, uncertainty of the amount of passenger baggage, turnaround time maintenance, congestion at the ramp at peak hours etc. (Acharjee et al, 1999). In Sweden, for instance, the amount of goods accompanying a regular domestic flight is very small (<100kg/flight) (Larsson 1998). But for international flights the amount of accompanied goods is larger.

## **2 AIM OF THE PAPER**

The objective of this paper is to find ways to promote the possibility to offer a shorter door-to-door delivery time through utilizing the empty belly capacity in passenger aircraft. The paper also investigates if a more efficient utilization of the belly at the daytime can generate a new 'overday' concept of processing airfreight and thus achieve a more significant share of the market.

## **3 METHOD**

The research approach, to fulfill the objective of this paper, is of a combination character. It is a combination of systems and analytical approach. For a process investigation (which is the first part of this study) possible relationship between systems must be understood. In the method of proceeding towards that goal the actors will be identified and their activities in the different systems (connected to each other in the whole process of line based air-traffic) will be clarified. The problem factors will be analyzed and the possible strength of those detected factors will be point out. In traditional analytical research the test of hypotheses is vital. Analytical approach in this case is not from a 'hypotheses testing' perspective but of an explorative nature. The analytical approach here is the verification of the strength of the detected problems and also, measuring of

possibilities to tackle the problems through inputs from more actors in the process. The steps are as follows:

- Identify the actors in the airfreight flow and understand their activities in line-based traffic
- Understand factors that hinder belly utilization
- Analyze the influence of those factors on goods flow and estimate possible strength of those factors.
- Verification of the estimated strength through questioning the airfreight actors on the level of control over the hindering factors. Transform the qualitative data to quantitative data to conclude how belly could be utilized better and if a better utilization might generate a new concept of processing airfreight - that is, utilization of the passenger aircraft belly at the daytime.

## 4 PROCESS IDENTIFICATION

### 4.1 Actors and activities

A number of actors participate in the process of the airfreight flow in line based traffic. The flow is a combination of activities taken care of by a few or all of these actors — customers, forwarders, terminal handlers, ramp handlers, and air companies. In most of the cases the forwarders deliver the freight to the airport. The freight can even arrive at the airport directly from the customers, means that the customers take care of the transportation themselves. The terminal handlers receive the goods and prepare (palletize or pack) them to be taken by the ground handlers to the aircraft. The goods can even be trucked from the airport to shorter geographical territories. In that case the terminal handlers load the goods to the trucks.

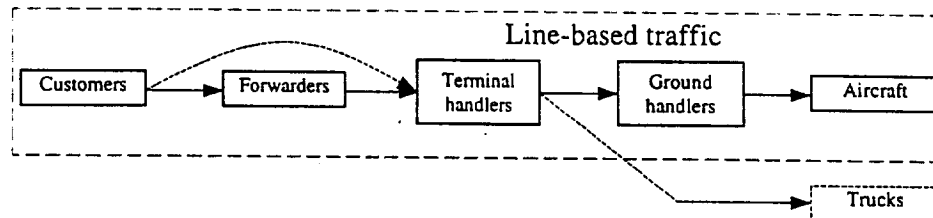
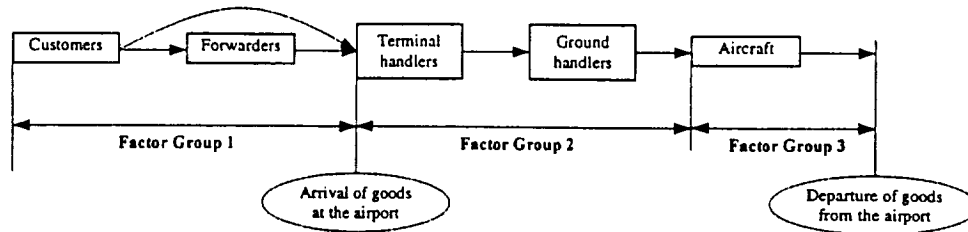


Figure 2: Actors in the process of airfreight flow

### 4.2 Hindering factors

In order to understand what causes a poor utilization of the belly, a study of the freight process were made at the Landvetter Airport in Göteborg (the second largest airport in Sweden). In the first phase, the study looked at the process of how the goods are treated on its way from the airport terminal to the aircraft. Through interviewing the personnel engaged in operations, factors that generate a low utilization were noted. It was understood that a poor utilization of the belly is caused not only by certain operational inefficiencies in the airport but also by various other factors. In fact, the majority of these factors lie outside the operational inadequacies in the airport. In the second phase of the study a number of airline operators were interviewed. The

airline interviews were extended later to the largest airport in Sweden (Arlanda Airport, Stockholm) to have a better view on the problem as a whole.



**Figure 3:** Different hindering factor groups and their position in the system

The hindering factors found out in the whole study are divided into three main groups (figure 3). Each of the groups is further divided into different subgroups of factors (table 1), named as 'Factor Group 1', 'Factor Group 2' and 'Factor Group 3'. A hindering factor, termed as '*Priority maintenance*', has been placed in 'Factor Group 1' under subgroup 'strategic factors' although this factor concerns the physical handling of goods at the airport. This factor could be argued to be placed in 'Factor Group 2' under 'operational factors'. The reason why it is placed under 'strategic factors' is that '*Priority maintenance*' is considered more as a strategic than as an operational issue.

	Factor Group 1	Factor Group 2	Factor Group 3
	Outside the airport	At the airport	Aircraft
Subgroups	<ul style="list-style-type: none"> <li>• Market-related factors</li> <li>• Strategic factors</li> <li>• Delivery-related factors</li> </ul>	<ul style="list-style-type: none"> <li>• Operational factors</li> </ul>	<ul style="list-style-type: none"> <li>• Unavailability issues</li> <li>• Incompatibility issues</li> </ul>

**Table 1:** Factor groups and their subgroups along with their position (origin) in the system

#### 4.2.1 Factor Group 1

'Factor Group 1' denotes hindering factors that are not caused by any operational inadequacy in the airport. This can otherwise be expressed as factors not related to the physical handling of goods in the airport. This group contains three subgroups of factors. These are 'market-related', 'strategic' and 'delivery-related' factors.

##### 4.2.1.1 Market-Related Factors:

The competitive forces in the airfreight market cause this group of hindrances. These are:

1. *Emergence of integrators:* The integrators, although traditionally had been dealing with documents and small packets, have diversified their service and have achieved a significant share of the market. This has deteriorated belly utilization.
2. *Competition in short destination flights:* The short destination flights contain less freight than the long destination ones since it costs the customers much more to send the freight by air

than by truck. If logistically the freight is to be transported fast according to the customer, only then the airlines are asked for the service in short distant flights. Consequently, for the short destination flights there used to be a huge empty capacity.

#### 4.2.1.2 Strategic Factors:

Different strategies that airlines have in their operations cause this group of hindering factors. These are:

1. *Priority maintenance*: There are many activities that take place during the turnaround process for an aircraft. The passengers get the highest priority to be boarded into the aircraft. Then comes the baggage of the boarded passengers, the post and then freight with the lowest priority. This means that if there is not enough time for the freight to get the flight, the freight is left back at the airport.
2. *Smaller capacity aircraft*: Type of aircraft is very important for a good capacity in the belly. Wide-body aircraft is freight friendlier than slim-body aircraft. The demand of the industries is, generally, shipment of bigger volume freight. For the demanded volume of shipment, for the distribution and logistics it is very difficult to reach a solution based on capacity in the slim-body aircraft. Also, if the passenger volume is not much then generally an even smaller type of airline is used, which is even worse for the huge amount of freight.
3. *Use of belly freight only for express delivery*: Different airlines have different strategies with the pricing of the belly airfreight. For some airlines belly is an express freight and should be paid accordingly, i.e. a higher price. They do not want to ship normal freight through the belly even if there is empty capacity.
4. *Separate organizations*: For some airlines the cargo and passenger units are separate organizations and the cooperation between them is often poor resulting a worse business. The passenger unit wants the best of the passengers and does not want to think about the benefit of the cargo unit if that collides with the benefit of the passenger unit. When, for example, it concerns purchasing of new aircraft they prioritize issues like speed, environmental-friendliness of the vehicle and even cost for the runway while the weight of the aircraft exceeds a certain capacity.
5. *Fueling*: Sometimes the aircraft takes fuel in a place where the price is cheaper. This increases the weight of the airlines that results less freight in the belly. Also, for longer destinations the aircraft must contain a huge amount of fuel, which also decreases capacity in the belly.
6. *Capacity problem in HUB*: The HUB might have limited capacity and cannot process goods when it exceeds a certain amount. This might cause the flights not to exceed certain load so that the ultimate pressure in the hub does not exceed its capacity.
7. *Prioritizing permanent customers*: There is often a problem with the permanent customers that they deliver more (or less) than they are supposed to. The deviation is not informed earlier to the airline which makes it difficult to plan the load. If the arrived goods are much more than informed, others' freight is unloaded prioritizing the goods of the permanent customers. These customers even send less goods than they are supposed to. In that case the belly utilization is less because by that time they had already refused to take goods from other customers assuming that the permanent customers would send the promised amount of goods.

8. *Concentration on pure freighter*: As the airfreight market is increasing very fast some of the airlines using pure freighters to tackle the demand. Thus, dependency on belly goes down which results in no concentration in planning of a better utilization of it. Passenger prioritization for these airlines rises even higher, which results in a less belly capacity.
9. *Less cooperation with the customers*: The forwarders generally do not let the airlines to be involved in the relation between the forwarders and their customers. Information that could directly be conveyed to/from the customers goes via forwarders instead and thus it takes longer time to solve the problem.
10. *Deadline to deliver freight at terminal*: Deadline of delivering the goods for belly traffic might vary between airlines. Sometimes the time (demanded by the airlines) for operations on the goods at the terminal might be more than necessary. If the deadline (for customers) to deliver the goods at terminal is increased, the airline could get some more customers and thus process more freight for the belly.

#### 4.2.1.3 Delivery-Related Factors:

This group of hinders are caused by the customers or the forwarders while delivering goods to the airport. These are:

1. *Goods arriving the terminal mostly at the same time*: The goods arrive at the airport mostly in the evening. The airplanes, on the other hand, run all day long. This points out to an uneven utilization of belly capacity. Moreover, to some destinations it is too late to ship the goods in the evening since the goods cannot be custom-checked in the destination airport and thus can not reach the customers in the same evening. (Moreover, the fact that most of the goods arrive at the same time can mean a quality problem in the handling of the goods.)
2. *Late arrival of the goods at the airport*: Late arrival of the goods at the airport may cause planned shipment cancelled.
3. *Wrong information about the shape/weight of goods*: It might be a problem to load the goods if incorrect information about its shape or weight is received. Belly has shape and weight constraints. If the information about the weight or shape is wrong, it may lead the plane to leave the airport without carrying the goods.

### 4.2.2 Factor Group 2

Factor Group 2' represents hindering factors that are caused by operational inadequacies at the airport, more precisely, at the apron. This group contains a single subgroup of factors. This subgroup is termed as 'operational' factors.

#### 4.2.2.1 Operational Factors:

This group of hinders are caused by inefficient operation on the goods after the goods are delivered at the airport until loaded into the aircraft. These are:

1. *Congestion at ramp at the peak hours*: Sometimes congestion at ramp (caused by different servicing vehicles at the ramp) at the peak hours constrains the loading possibility.

2. *Weight limitations of handling equipment at the ramp:* Sometimes the mechanical equipment cannot handle weights of certain capacity for the belly cargo to be utilized. Even if the source airport is equipped, the destination airport might have insufficiency to handle certain amount of weight.

### 4.2.3 Factor Group 3

Factors described in Factor Group 3' are related to problems around the aircraft. Hindering factors in this group are caused by aircraft unavailability and also incompatibility of aircraft capacity with the amount of goods to be loaded. This capacity minimization could be due to less time for loading the goods or due to less physical capacity in the aircraft resulting whole or part of planned shipment cancelled.

#### 4.2.3.1 Unavailability Issues:

Belly utilization is decreased through unavailability of the aircraft in the terminal. The following factors can cause aircraft unavailability:

1. *Cancellation of the aircraft:* Cancellation of flights due to technical or other problems makes planned shipment often cancelled. It is easier to manage with the passengers rerouting their journey. Because the transfer time (in a third airport) is much less for the passenger than for the freight.
2. *Non-arrival of scheduled flight:* Non-arrival of scheduled flights (because of cancellations in the source airport) makes planned shipment cancelled.

#### 4.2.3.2 Incompatibility Issues:

Even if the aircraft is available, the aircraft capacity might be incompatible with the amount of goods to be loaded. Incompatibility might be generated due to less loading time or less physical capacity in the aircraft. The following factors may cause incompatibility:

1. *Late arrival of the aircraft:* Late arrival of the aircraft makes the turnaround time shorter. The aircraft turnaround time is very important to maintain because it plays a vital role for the image of the airlines. If an incoming flight arrive late at the airport, scheduled loading of freight might be cancelled or the amount allowed might be less in order to maintain a fast turnaround. Certain type of goods (big pallets, for example) is hard to load in a shorter turnaround time.
2. *Unexpected amount of passenger baggage:* Amount of passenger baggage may vary because of unanticipated amount of passengers. Even with the same amount of passengers, the baggage amount may vary. In a slim-body passenger aircraft Generally 1000 to 3000 kg's of freight is possible to load after loading the baggage of the passengers. But sometimes this estimation does not work because of uncertain amount of luggage enter the belly leaving a few or almost no capacity to be used by the freight. Preventive measures could be taken in order to increase the probability of utilization of the belly.
3. *Sudden change of aircraft:* If number of passengers is less than anticipated the planned aircraft may be changed to a smaller type. This might cancel planned shipment.

4. *Weather conditions minimizing lifting capacity:* Weather conditions (like headwind) in specific geographical locations sometimes limit the aircraft to exit certain weight. The belly gets affected since it has the last priority to get the aircraft.

## 5 ANALYSES OF FACTORS

In this section, the impact of the hindering factors (that are identified through interviews with the different actors) on the whole process of belly utilization will be analyzed.

Factor Group	Number of hinders contained	% of total
1	15	65
2	2	9
3	6	26

**Table 2:** Share of factor groups causing less belly utilization

The hindering factors in FG1 (Factor Group 1) minimize the possibility of delivering the freight to the terminal (figure 3). Which means, the less the strength of the factors in this group the better it is for the availability of freight at the airport. The hindering factors in FG2 complicate the chances of the existing freight to be transported to the belly and thus minimize the belly utilization. Factors in FG3 minimize it even further. The less the strength of the underlying hindering factors (i.e. the less the possibility that a certain constraining factor will occur) the more the possibility of a better belly utilization. FG1 (with the underlying factor groups — market related factors, strategic factors and delivery-related factors) appears to be the strongest (at least in quantity of hindering factors) among all the groups. FG2 contains the lowest number of factors. If the goods flow will be much more (that is if influence from FG1 is less) than new operational hinders and also strengthening of mentioned hinders might occur weakening the belly utilization. More goods flow might even strengthen the factors belonging to FG3.

Even if more hindering factors might be generated or strengthening of the existing hinders might occur, these should not prevent more goods flow at the airport. Along with the generation of hinders, preventive measures should also be taken and implemented.

As we can see in table 2, FG1 contains 65% of the all the hindering factors. FG2 and FG3 contain 9% and 26% of the factors respectively. If we consider that each of all the 23 factors described above weigh the same, FG1 obviously draws the concentration. The second argument to concentrate mostly on FG1 is that there must be goods at the terminal in order to process it all the way to the aircraft.

## 6 ACTOR VERIFICATION

In this section, the estimated strength of the factor groups analyzed in the previous section will be verified with the quantitative data collected through a questionnaire survey. The survey includes three main commercial airports in Sweden, which are Stockholm-Arlanda, Göteborg-

Landvetter, and Malmö-Sturup. For each of the airports, main actors (or airlines) utilizing passenger aircraft belly for freight flow were defined. The different ground-handling companies operating in the respective airports were contacted in order to know who the main actors were. After being informed about the main actors, they were contacted and people best suited to the goal of the survey were searched for. After being convinced that the right person (to answer to the survey) for each of the airlines was found, the questionnaire was sent to the respective person. The total number of questionnaire sent to the actors was 20. To be mentioned that for a single airline one individual answered to the survey representing the respective airline's operations in two airports. Thus, the data received in a single questionnaire represents experiences of two different airports (i.e. one additional airport). There was also a case where a single airline was responsible for freight operations for two additional airlines. In this case, the data received in a single questionnaire represents three airlines. This means that although the total number of questionnaire sent to the actors was 20, they were responsible for data on more than 20 operations. 12 of the 20 questionnaire were answered, which denotes a response of 60%. Taking into account that one person answered for a single airline's operation in different airports and a single airline answered also for different other airlines, 15 (i.e. 1+2+12) of the 20 questionnaire were answered denoting a response of 75%.

The airlines surveyed were - KLM, SAS, British Airways, Air France, Finnair, Thai Airways, Swissair, Sabena, Austrian, Aeroflot, Premiair, Malmö Aviation, Novair, Iberia, and Delta Airlines.

Two questions were mainly focussed in the survey. The first one was to estimate the degree of influence each of the hindering factors had on the operations of the actors. The second one was to estimate how the actors considered the possibility to eliminate the hindering factors. Figure 4 demonstrates the influence of the factors and the possibility to eliminate the factors as received through the survey.

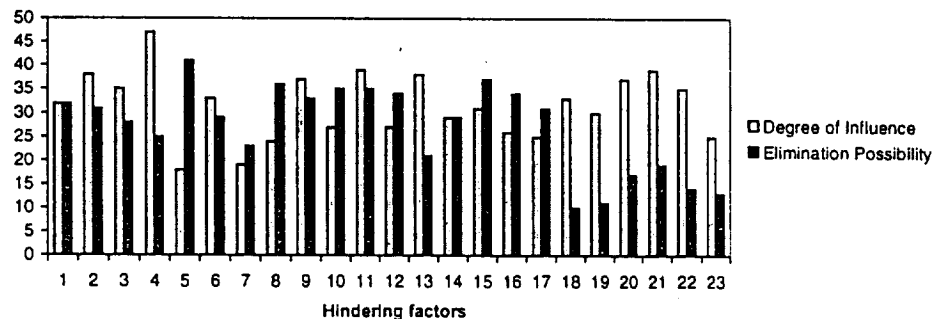


Figure 4: The degree of influence of different hindering factors and their possible elimination

To be mentioned that all the respondents answered to the first question and only one of the received questionnaire did not have any answer on the second question. In order to have a good



comparison, data on the second question needed to be adjusted<sup>1</sup>. Table 3 shows survey data on both the questions including the adjusted data for the second question.

Hindering factors	Degree of Influence (A)	Elimination Possibility (original) (B)	Elimination Possibility (adjusted) (C)	Difference (A-C)
1. Emergence of integrators	32	29	32	0
2. Competition in short destination flights	38	28	31	7
3. Priority maintenance	35	26	28	7
4. Smaller capacity aircraft	47	23	25	22
5. Use of belly freight only for express delivery	18	38	41	-23
6. Separate organizations	33	27	29	4
7. Fueling	19	21	23	-4
8. Capacity problem in HUB	24	33	36	-12
9. Prioritizing permanent customers	37	30	33	4
10. Concentration on pure freighter	27	29	35	-8
11. Less cooperation with the customers	39	32	35	4
12. Deadline to deliver freight at terminal	27	31	34	-7
13. Goods arriving the terminal mostly at the same time	38	19	21	17
14. Late arrival of the goods at the airport	29	27	29	0
15. Wrong information about the shape/weight of goods	31	31	37	-6
16. Congestion at ramp at the peak hours	26	28	34	-8
17. Weight limitations of handling equipment at the ramp	25	28	31	-6
18. Cancellation of the aircraft	33	9	10	23
19. Non-arrival of scheduled flight	30	10	11	19
20. Late arrival of the aircraft	37	16	17	20
21. Unexpected amount of passenger baggage	39	17	19	20
22. Sudden change of aircraft	35	13	14	21
23. Weather conditions minimizing lifting capacity	25	12	13	12

**Table 3:** Surveyed strength of the different hindering factors and their possible elimination

If we accumulate the surveyed strength (table 3) of all the hindering factors according to the three factor groups, we can analyze the hindering strength that each factor group has in the operation.

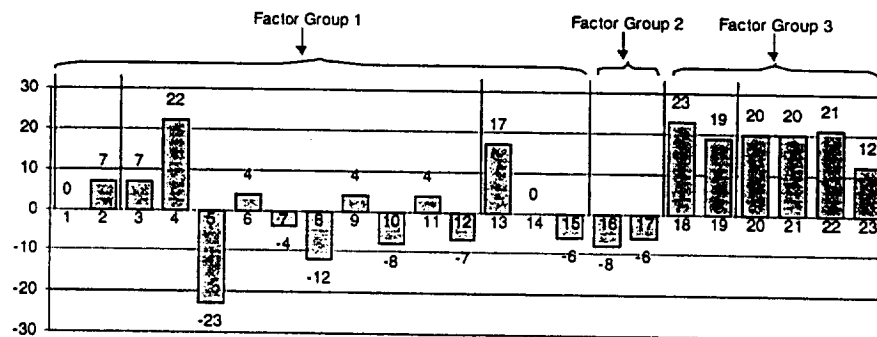
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<sup>1</sup>  $C = B \times \frac{12}{11}$

Factor Group (FG)	# of underlying factors in FG	Sub-factors	Accumulated strength of underlying factors	Accumulated strength of FG	Average strength of each hinder
1	15	Market-related factors	70	474	31.6
		Strategic factors	306		
		Delivery-related factors	98		
2	2	Operational factors	51	51	25.5
3	6	Unavailability issues	63	199	33.1
		Incompatibility issues	136		

**Table 4:** Hindering strength of each factor group

As we can see in table 4, FG1 has the biggest influence among all the factor groups with an average strength of 31.6 for each underlying hinders. Although this average is less than the average hindering strength of hinders in FG3, the superiority in total number hinders (in comparison to that of FG3) makes the dominance of FG1. On the other hand, if we compare the hindering strength with the possibility of their elimination, we can see (figure 5) that elimination of the factors underlying in FG1 is relatively easier than elimination of factors in FG3.



**Figure 5:** Differences between hindering strength and eliminating strength

It is obvious that in order to generate a better goods flow at the airport, it is necessary to reduce the strength of factors in FG1. Also, according to the data, it is relatively easier to confront this group of hinders. If, after taking care of strategic or other changes, the strength of FG1 is reduced creating a better goods flow at the airport, this will increase hindering strength of factors in both FG2 and FG3 provided the underlying hinders are not reduced. If (in relation to a better freight flow) the operational inefficiency at the ramp is not increased or the required capacity is not compatible with the amount of goods, the reduction of hindering strength in FG1 would mean nothing. This necessitates concentration on FG2 and FG3. According to figure 5, it seems that the actors are able to have better control on the factors in FG2. When it concerns FG3, the ability to control the underlying factors seem not to be satisfactory.

## 7 CONCLUSIONS

As the aircraft-turnaround time is limited the cargo is de-prioritized enters the aircraft latest in the process. In the study, we have found that for a planned belly shipment to be made, the aircraft

must stay at the ramp no less than the duration of the planned turnaround time. This necessitates the aircraft to land on time. The different activities in the turnaround should also be performed effectively enough so that the time needed to load the cargo is available. Other deviations (e.g. change of aircraft to a smaller size etc.), that can minimize the capacity for cargo in the aircraft should not exist. The chances that deviations take place are not rare. Customers, that want to ship goods by air need fast transportation and pay relatively higher than they would have if transported by any other mode. In relation to the price that customers pay, the service level must be satisfactory. But as the different hindering factors worsen the chances of a shipment, this might make it harder for the operators to motivate themselves to think of making customer relations based on the empty belly utilization in passenger aircraft. Improved control over the hindering factors, especially those related to the apron and the aircraft (i.e. FG2 and FG3) can motivate the actors to make better customer relations and promote possibility to utilizing the belly more efficiently as chances to more satisfactorily serve the customers are higher. These factors hinder flow of goods in the airport, i.e. from the goods terminal to the aircraft belly. Hindering factors that exist outside the airport area (i.e. FG1), hinder goods flow from the customers to the airport. Before reducing the impact of FG2 and FG3, reduction of the impact of FG1 would mean more goods at the airport creating more pressure with the limited capacity. That is why we stress on improvement especially in FG2 and FG3. It is clear from the survey that the underlying factors in these two groups are not easy to tackle. Factors related to unavailability issues, like cancellation or non-arrival of scheduled flights are very much problematic since it is hard to ship the goods through connecting routes (i.e. as done with the passengers). Preventive measures should be taken for both the unavailability and the incompatibility issues in order to improve the underlying hinders as much as possible. The improvement will assure more goods to be shipped, the actors then can concentrate on reducing factors underlying in FG1 in order to have a better goods flow to for the belly to be utilized.

The aim of this paper was also to analyze if a more efficient utilization of the belly at the daytime can generate a new 'overday' concept of processing airfreight and thus achieve a more significant share of the market. Integrators, as we know, have a concept of 'overnight' delivery of goods and they are quite successful with this concept triggered by the fact that they have the goods available at the airport in the evening for shipment. They own all the assets (e.g. different vehicles, information system, etc. that are necessary) in the whole process of their services. Consequently, they have a good control over the freight flow and can effectively deliver the goods. Belly's flexibility, on the other hand, lies with the frequency of the flights. But, as most of the goods arrive at the terminal in the evening, this frequency does not mean a lot for the operators. The result shows also that the control is not satisfactory over the hinder. In order to look forward to generating an 'overday' concept, hinders underlying in all the factor groups should be minimized as much as possible so that more freight flow is generated at the airport and satisfactory service is provided. The airlines have to realize that their service has contributed to build up the customers' 'trust'. As day-time is not an appropriate hour for the shippers to deliver the goods at the terminal, tempting propositions should be made by the airlines so that the customers are interested to deliver goods all over the day. It needs further research to judge whether it is possible to generate a 'overday' concept of passenger aircraft belly utilization as it depends on how much of the hindering impact the airlines are willing to minimize. It depends also on how closely the actors then (with reduced hindering impact) cooperate with each other and exploit the advantages and disadvantages through such a process.

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## **Re-examining the Slot Allocation Problem**

Vanessa Tamms  
Australia-Japan Research Centre  
Asia-Pacific School of Economics and Management  
Australian National University  
Ph: +61 2 6249 5532  
Fax: +61 2 6249 0767  
Email: [vanessa.tamms@anu.edu.au](mailto:vanessa.tamms@anu.edu.au)

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### **Abstract**

This paper puts forward the case for re-examining the feasibility of using auctions to allocate take-off and landing slots at airports in light of the success of the US radio spectrum auctions. It discusses how the simultaneous multi-round design of the spectrum auctions would need to be adapted to accommodate combinatorial and contingency bidding behaviour, given the synergies inherent in operating particular combinations of slots and the substitutability of slots within certain time intervals. It also highlights how broad cooperation would be required to implement such a system across airports located in many different countries. Finally, it suggests that the right to provide services also be embodied in the definition of a slot in order to ensure that auction outcomes are efficient.

## Introduction

The past decade has witnessed liberalisation of international air transport markets. Many countries have substantially deregulated their domestic markets, privatised their national "flag carriers", and permitted multiple designation of carriers on international routes. Many have also entered into agreements with other countries which seek to liberalise markets between themselves and the partner country. The European Economic Area<sup>1</sup> (EEA) countries, for example, have established a Common Aviation Market (CAM) by replacing the bilateral Air Services Agreements (ASAs) which formally governed trade in air transport services among them with a multilateral agreement. The US has so far replaced 33 of its ASAs with "open skies" agreements (liberalised bilateral agreements), and Australia and New Zealand have established a Single Aviation Market (SAM) across the Tasman.

Despite these moves, significant barriers to trade in air transport services remain. Foreign investment remains highly restricted, and hence the liberal terms of the replacement agreements generally only apply to carriers registered in signatory countries. The provision of cabotage services also remains prohibited, except for under the CAM and SAM agreements which permit this by carriers based in signatory countries only. These restrictions have not only prevented third-country carriers from providing services in particular markets, but in most cases also carriers from providing domestic services in a foreign country. They have also restricted carrier mode of supply to "production" in the country of registration and "export" abroad.

In addition, airport- and ticket-sales-related issues have received little attention from regulators, with two exceptions. The EEA has issued Council Directive 96/67/EC on access to ground-handling services, which permits EEA carriers to self-handle land-side at all EEA airports, and self-handle airside at all EEA airports with 1 million passengers and/or 25 000 tonnes of freight or more per annum. Ground-handling by third parties is also currently being phased in<sup>2</sup>. The General Agreement on Trade in Services (GATS) includes an Annex on Air Transport Services, which seeks to make aircraft repair and maintenance, travel agent and computer reservation system (CRS) services consistent with the transparency, non-discrimination and national treatment rules of the world trading system. However, the majority of GATS signatory countries were granted exemptions from the three Annex provisions, such that at present the Annex is virtually ineffective<sup>3</sup>.

This paper focuses on the allocation of take-off and landing slots at major airports, one of the airport-related issues which has received virtually no attention from regulators. It describes methods currently used to allocate slots, and explains how these not only make significant competitive new entry difficult, but also prevent incumbents from operating efficient networks. It also puts forwards the case for re-

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<sup>1</sup> The 15 Member States of the European Union plus Norway, Iceland and Liechtenstein.

<sup>2</sup> This is scheduled to be in place at all EEA airports with 2 million passengers or 50 000 tonnes of freight or more per annum by 1 January 2001 (Official Journal of the European Communities No L 272, 25/10/96; 36).

<sup>3</sup> A new round of negotiations is scheduled to begin in 2000, at which time these exemptions will expire.

examining the feasibility of using auctions to allocate slots, given the success of the US radio spectrum auctions and the similarities between the tasks of allocating spectrum and slots. It also highlights how the design of the spectrum allocation mechanism would need to be adapted to accommodate combinatorial and contingency bids given the complementarities among, and substitutability of, airport slots, and how broad cooperation would be required to implement such an allocation system across the world's major airports, given that these are located in many different countries. Finally, it puts forward the case for embodying the right to provide services as well as the ability to take-off and land in a slot as in the case of radio spectrum, reducing the current two-step procedure to a single step and improving efficiency.

## **Section I: Methods Used to Allocate Slots at Major Airports**

### **The IATA System**

Historically slots were largely allocated on a first-come first-served basis. As air traffic grew, however, airport congestion grew and so did delays. Airlines subsequently established scheduling committees at major airports which aimed to better coordinate take-offs and landings such that delays would be minimised. By 1993 there were over 100 of these committees in operation around the world<sup>4</sup>. Traditionally the committee at each airport consisted of staff on secondment from the major incumbent airline serving that airport. However, it is now a requirement that at fully coordinated airports (airports at which demand is greater than supply at most times of the day) a panel consisting of the carriers which are the largest providers of services at these airports oversee the process<sup>5</sup>. Before each season commences, the airport authority, on advice from air traffic control, determines the feasible number of aircraft movements (take-offs and landings) at each hour of the day. Carriers currently serving or wishing to serve a particular airport submit their slot requests to the scheduling committee of that airport, and the committee allocates slots among carriers based on their requests and the feasible number of movements.

At times of the day where demand for slots outstrips supply, committees allocate slots according to rules set out by the International Air Transport Association (IATA), the trade association for airlines. These rules give priority to carriers which request slots they used in a previous equivalent season (summer or winter), then carriers wishing to change the times of existing services, new entrants, carriers wanting to extend existing services to year-round operations, and then carriers whose schedule will be effective for a longer period of operation in a particular season<sup>6</sup>. Since 1990 IATA rules have required that 50% of unclaimed slots, slots that become newly available, or those surrendered under the "use-it-or-lose it" rule in each time

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<sup>4</sup> Jones, Viehoff and Marks (1993); 40

<sup>5</sup> The chair of the panel is still generally a former employee of the major incumbent airline: at London/Heathrow, for example, the chair is a former British Airways employee.

<sup>6</sup> If slots are still available and there are requests for these, secondary criteria are used to allocate them. These include: the need for a mixture of long-haul and short-haul operations at major airports, the effect on competition, consideration of curfews at other airports, and requirements of the travelling public and other users (IATA (1998), *Scheduling Procedures Guide*, Twenty-Third Edition, January; 10).

period be allocated to new entrants, where new entrants are defined as those carriers which hold no more than four slots per day at the airport in question. The IATA rules have basically been accepted into European Union (EU) law, with the exception that the definition of new entrant has been extended to airlines seeking to provide competition on intra-EEA monopoly and duopoly routes which hold fewer than four slots a day for that service, provided that they are seeking no more than a twice daily service, under Council Regulation 95/93 adopted in 1993. Any airline with more than 3% of all slots at an airport or more than 2% of slots at an airport system cannot qualify as a new entrant<sup>7</sup>.

Given that each airport scheduling committee makes its decisions independently, IATA Schedule Coordination Conferences are held bi-annually to enable airlines to coordinate their schedules worldwide. At these conferences, carriers are able to swap slots with others under antitrust immunity, in order to try to obtain slots they still require or consistent sets of arrival and departure times. They may trade slots at different airports and alter the type of aircraft flown, subject to the approval of the relevant scheduling committees. However, no money may change hands, which means that often trades need to involve many parties simultaneously, making the task complex and time-consuming. Trading can also take place after the conference on an ad hoc basis<sup>8</sup>.

The priority given to "grandfathering" means that the majority of slots at congested airports, particularly during peak periods, are retained each season by incumbents. The few slots (if any) which are available will tend to at non-peak times and inconsistent across days of the week. This has severe consequences on competition and efficiency given the nature of passenger demand and the economics of providing air transport services. Studies have shown that passengers, particularly time-sensitive passengers, prefer frequent services on short-haul routes: airline yield increases more than proportionally the greater the number of daily frequencies a carrier offers on a particular route as business passenger numbers increase more than proportionally<sup>9</sup>. Passengers also prefer interlined consecutive services, as collecting baggage and re-checking in is not necessary on these at intermediate stops. They also show a preference for carriers on whose flights they can accumulate frequent-flyer points<sup>10</sup>. There is also substantial evidence that there are significant economies of traffic density inherent in the provision of air transport services: an increase in network traffic, via an increase in flight frequency per route, greater average load factor, or through consolidating passengers onto larger aircraft will decrease a carrier's average costs<sup>11</sup>.

Carriers will thus aim to provide high-frequency, well-interlined services on which passengers can earn frequent-flyer points in order to satisfy passenger demand and achieve the maximum cost-savings inherent in the provision of their services. Under the IATA system of slot allocation, however, both new entrants and

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<sup>7</sup> Official Journal of the European Communities No L 14, 22/1/93.

<sup>8</sup> Jones, Viehoff and Marks (1993); 41.

<sup>9</sup> This phenomenon is known as the "origin-point-presence effect" or the "s-curve effect" (Tretheway and Oum (1992)).

<sup>10</sup> Morrison and Winston (1989), using 1983 US data, found that on average passengers were willing to pay an additional US\$32 per round trip in order to accumulate frequent flyer points.

<sup>11</sup> Caves, Christensen and Tretheway (1984).



incumbents are restricted in their ability to do this. New entrants are unlikely to be allocated sufficient quantities of peak-period slots consistently timed across the week which would enable them to provide high-frequency, well-interlined services and hence compete effectively with incumbent carriers. Experience in the EEA shows that carriers which have been allocated slots from the 50% of the slot pool reserved for new entrants have not subsequently begun providing services on short-haul routes in competition with incumbents; rather, they have either handed them back, used them to increase frequency of service on routes they already serve, or begun providing long-haul services<sup>12</sup>.

The prohibition of slot sales further hinders new carriers from entering markets. As already mentioned, the IATA system only permits slot swaps, and hence carriers must initially have something to swap in order to take part in this process. Slot sales allegedly take place in post-conference trading, disguised as slot swaps: carriers exchange slots, where this is accompanied by an under-the-table financial payment from the holder of the slot with the lower market value to the holder of the slot which has a higher value. Even carriers which have not been allocated slots at the airport in question can take part in this by applying for an off-peak slot, at say 5am and then "swapping" this for the slot they desire. The slot obtained by the other carrier is subsequently returned to slot pool under the "use-it-or-lose-it" rule of the IATA system. However, it is unlikely that a new entrant will be able to acquire either the number or the type of slots it would require to establish viable services on short-haul routes, especially when some of the potential trading partners are carriers which it would compete directly with should it be able to acquire them. Even if slots allocated could be bought and sold, however, new entrants would be at a disadvantage as they would be forced to pay for something which incumbents were initially allocated free of charge.

Obtaining the necessary slots is likely to become more of a problem over time given the increasing number of airlines establishing inter-carrier alliance agreements, as not only will the pool of sellers shrink, but also new entrants will have to provide more frequencies in markets where the partner carriers both provide services and coordinate their schedules. New entrants could themselves enter into code-sharing or block-purchasing agreements with carriers already serving the markets in which they wish to operate. However, this only allows them to indirectly serve these markets. In addition, their ability to do this will also depend on the success they have in finding a partner, which in turn will depend on the extent to which incumbents already have such agreements with the new entrant's competitors.

A carrier may be able to begin providing services in particular markets if a second airport exists in a city which can accommodate the type of services also operated out of the first and it itself is not slot-constrained at peak periods. However, these airports are often not perfect substitutes for one another: time-sensitive passengers in particular often prefer one airport over another due to locational or other factors. In London, for example, many passengers show a distinct preference for Heathrow Airport compared to Gatwick, given the former's closer proximity to the centre of London and its greater number of connection possibilities<sup>13</sup>. These airports

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<sup>12</sup> UK Civil Aviation Authority (1998).

<sup>13</sup> GRA Inc (1996) state that yields on Heathrow services are of the order of 10% higher than equivalent Gatwick services.

will become closer substitutes the longer the flight-length or the greater the price differential between the same flight operating out of the primary and secondary airports. Experiences in the US and the UK show that secondary airports are extremely effective substitutes if the price differential is large enough: Southwest Airlines and easyJet operate out of Dallas/ Lovefield and London/ Luton respectively<sup>14</sup>. Indeed, carriers can even viably provide low-frequency, non-interlined services which do not provide frequent-flyer benefits at non-peak times of the day if airfares are sufficiently low.

It is not necessarily the case that new-entry is more beneficial than an increase in services by incumbent carriers. Indeed, the smaller the number of slots obtained by the entrant, the more likely it is that incumbents could have used these more effectively. For example, an incumbent may use them together with slots it already has to begin providing services in new markets in competition with other carriers, which not only leads to a reduction in airfares in these markets, but also improves the connectivity of its network and offers its passengers more ways to earn frequent-flyer points and redeem accumulated mileage. Alternatively, it may use them to begin providing services in a market not currently served, which may provide greater benefits to passengers than through having a new competitor in a market already served. Even if the new entrant uses the slots in the same way in which the incumbent way planning to use them, it may be the case that the incumbent is more efficient than its new entrant counterpart, and hence that additional inefficiencies are being introduced into the market.

The difficulties experienced in obtaining slots by would-be new entrants protects incumbent carriers from competition, enabling them to price their services above the long-run competitive level. However, this must be traded-off against the fact that they are similarly unlikely to be allocated slots which would enable them to add to their existing route networks. Indeed, they may even be unable to obtain the necessary slots to add frequencies to routes they already serve in order to more fully capture economies of density given that if they apply for new slots their request receives lower priority than those of new entrants. In order to begin operating new routes or increase flight frequency, incumbents must thus sacrifice services they currently provide such that the slots they require become available. This limits the extent to which carriers can respond to passenger demand and capture savings from economies of traffic density.

An additional problem with the IATA system is that it is not internationally binding. In practice this means that allocation is prone to intervention by national governments reacting to political pressures, and that there is little adversely affected carriers can do about it except lodge complaints. A recent example of this occurring was the allocation of "new" slots at Tokyo/ Narita Airport in the second half of 1998<sup>15</sup>. When this occurs, the system is not consistent with the non-discrimination, national treatment and transparency principles of the world trading system.

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<sup>14</sup> Lovefield Airport is within closer proximity of the centre of Dallas than Fort Worth Airport; however, the latter has better connection possibilities.

<sup>15</sup> 202 "new" slots became available after the conclusion of a Memorandum of Understanding between Japan and the US; these were subsequently mainly awarded to Japanese and US carriers, most of which already have substantial presence at this airport. US carriers claim that these slots became available because a number of (unused) slots were surrendered by Federal Express and because the Japanese air

Finally, governments forego revenue from carriers which would normally accrue to asset-holders. This revenue could be used to improve the budget bottom line or provide tax-relief to corporations or individuals.

### The US System

The IATA system cannot be used to allocate slots at US airports<sup>16</sup>, as under US anti-trust laws US carriers cannot meet to discuss flight scheduling. Airlines simply schedule their flights taking into account expected delays at the busier airports<sup>17</sup>, except at the designated "high-density" airports: Chicago/ O'Hare, Washington/ Reagan National, New York/ John F Kennedy and New York/ La Guardia. Slots used for domestic services at these four airports have been subject to different rules since the introduction of the "High Density Traffic Airports Rule" by the FAA in April 1969. The rule established slot quotas for scheduled air carrier services, commuter services and general aviation at these airports.

Initially scheduling committees were set up at each of these four airports, where each consisted of committee staff and carriers serving or wanting to serve the airport in question. Unlike the situation at fully-coordinated airports which abide by the IATA rules, however, after all slot requests were received all members of a scheduling committee would meet together and multilaterally negotiate the withdrawal of requests for slots until the number sought equaled the number available at all times of the day. These meetings were granted anti-trust immunity; however, post-committee meeting gatherings to coordinate schedules across airports were not permitted. Importantly, any distribution of slots was required to be unanimously agreed upon by committee members; if agreement was not forthcoming within a certain time period the responsibility of allocating slots would be handed over to the FAA. The rules the FAA would use to allocate slots in such a situation, however, were unknown<sup>18</sup>. Grether, Isaac and Plott (1989) used controlled environment experiments to show that in such circumstances committee decisions will tend to be substantially governed by the perceived consequences of default. Larger carriers apparently thought that the FAA would grant new entrants at least a small number of slots, and hence "conceded" these in committee meetings in order to avoid default.

Initially the system encouraged new entry because potential entrants knew that they were almost guaranteed to gain some slots given their ability to cause the committee to default, but the scale of new entry was generally small. Many of the

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traffic controller's union agreed to raise hourly traffic movements. However, many of the slots which became available were at different times to the surrendered slots. There is industry speculation that these slots were "found" in order to appease the US given that the new (second) runway is unlikely to be fully operational for several years, and that the compliance of Japanese carriers was obtained in return for assurances that they would be looked upon favourably when the slots which become available prior to the opening of the new runway are allocated. The Europeans subsequently formally complained and threatened sanctions against Japan (*Airline Business*, August 1998; 28-29 and October 1998; 26).

<sup>16</sup> Agencies (usually the Federal Aviation Administration (FAA)) represent US carriers in IATA schedule coordination conferences which involve the trading of slots used for international services at US airports (Starkie (1992); 27).

<sup>17</sup> Starkie (1998); 113

<sup>18</sup> Grether, Isaac and Plott (1989).

outcomes of the system were similar to those of the IATA system: new entrants were not necessarily more efficient than incumbent operators, incumbents were prevented from expanding their services in line with passenger demand without sacrificing existing services and hence were preventing from fully capturing economies of traffic density inherent in the provision of their services. However, in addition, the system made it difficult for carriers to coordinate system-wide operations given that the decisions each committee were made independently of allocations at other airports.

Deregulation of US domestic aviation markets in 1978, however, led to increased demand for slots, making it more difficult for scheduling committees to reach consensus. The FAA was eventually forced to intervene in 1980 when new entrant New York Air sought a large number of slots in order to establish low-cost services between Washington/ Reagan National and New York, and it took slots from incumbents for redistribution among new entrants<sup>19</sup>. The system was suspended in response to the air traffic controllers' strike in 1981, and in 1982 carriers were permitted to transfer and to buy and sell slots for a six week period<sup>20</sup>. After this time slot transfers continued, and the FAA used lotteries to allocate any additional slots becoming available at these airports which contained special provisions for new entrants. In 1984 scheduling committees were reinstated; however, the same problems were encountered as before.

Given the increasing difficulties in reaching a consensus among scheduling committee members and the successful trial of the trading system, the "buy-sell" rule was implemented on 1 April 1986 at the four high-density airports. Under this rule, carriers are able to buy, sell, trade or lease their historic entitlements of slots used for domestic services in a secondary market<sup>21</sup>, where trades can be one-for-one or of uneven numbers of slots and accompanied by a financial payment. At all times, however, slots remain the property of the FAA. Slots set aside for commuter services cannot be bought by larger carriers, and the use of slots is subject to a "use-it-or-lose-it" rule<sup>22</sup>. Surrendered slots and others which become available are put into a pool and reallocated by lottery. 25% of these are reserved for new entrants<sup>2324</sup>.

Before the buy-sell rule came into effect, the FAA made 5% of slots at O'Hare, Reagan National and JFK airports available for reallocation to new entrants and incumbents with less than eight slots at these airports in response to criticism that

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<sup>19</sup> It was subsequently challenged (unsuccessfully) in the courts.

<sup>20</sup> Despite the uncertainty over how long the purchased rights would be valid, 194 sales took place during this period, and at least one firm initiated a slot brokerage program (Starkie (1992); 7).

<sup>21</sup> Off-peak slots and those used for fewer than five days/ week are allocated by the FAA. Slots identified by the Office of the Secretary of Transportation as required for Essential Air Services (EAS) are allocated directly to the carrier providing the service.

<sup>22</sup> Slots not used at least 80% of the time in a two month period must be returned to the FAA for reallocation.

<sup>23</sup> In January 1993 the definition of new entrant was broadened to include also incumbent carriers with only a few slots at these airports (Starkie (1998); 113).

<sup>24</sup> Each slot is also given a "priority number", assigned by lottery, which determines its priority for withdrawal. Slots can be withdrawn if the number required for international services which have been authorised via ASAs plus the domestic slots allocated for a particular time period exceed High Density Rule quotas to make a sufficient number available for international the international services. Similarly, slots can be withdrawn for EAS operations if not enough are available.

grandfathering slots favoured incumbents over entrants<sup>25</sup>. It rejected claims that a greater proportion of slots be made available as it was concerned that services to small and medium-sized communities would be affected and because incumbent carriers had given up slots in the past to permit new entry. It also rejected calls for similar withdrawals and reallocations to be held periodically in the future given that new entrants can purchase slots and be allocated them via lottery.

In practice, however, new entrants have experienced difficulties in obtaining slots which are to be used for scheduled services. This is because incumbents have tended to lease slots rather than selling them outright, and because both leases and sales have generally occurred between incumbents and carriers which would not be expected to compete vigorously with them<sup>26</sup>. When sales have occurred, for example, they have generally been between acquired carriers and their buyers<sup>27</sup>, incumbents and their commuter partners or to all-cargo companies. The few sales of slots have meant that new entrants have had few opportunities to purchase slots; the large amount of leasing activity among related carriers has not only meant that entrants have been unable to lease slots, but also that incumbents have been able to avoid having to surrender slots under the use-it-or-lose-it rule, and hence that there have been relatively few slots available in the slot pool. Not surprisingly the few slots which have been surrendered have been non-peak slots. The extent to which incumbents lease slots among themselves is likely to increase in the future given the increasing number of alliance agreements established among carriers.

Unlike the IATA system or the previous system used to allocate slots at the high-density airports, the buy-sell rule gives new entrants the right to buy and lease slots regardless of whether or not they already have slots. In addition, it gives the most efficient new entrants an upper hand, as, in the absence of government subsidies, the most efficient carriers will be the most profitable ones and hence be able to bid more, whereas under the other systems administrative discretion determines which carriers will be granted slots (IATA) or all carriers are automatically granted slots (former system used at US high-density airports). However, on the other hand, it prevents new entrants from successfully completing transactions by requiring them to buy and lease from potential competitors. Incumbents are able to determine who slots are sold and leased to, and hence can control the level of competition they face<sup>28</sup>. Given the relatively small number of slots in the slot pool and that these tend to be off-peak slots, the rule still requires new entrants to purchase the majority of the slots

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<sup>25</sup> This was done by withdrawing slots from incumbents using a reverse lottery: the FAA randomly selected "tickets" for each hour out of a "hat", where the number of tickets each incumbent had was proportional to slots held. The incumbent carrier holding the first ticket selected had first choice of which slots to surrender, the carrier holding the second had second choice etc. The withdrawn slots were allocated via lotteries in March and December 1986, where each new entrant was restricted to drawing a maximum of eight slots at each airport. Any slots surrendered not subsequently demanded were returned to carriers in reverse order of slots surrendered.

<sup>26</sup> Data which distinguishes between trade in air carrier and commuter slots is only available for the first three years after the introduction of the buy-sell rule; however, during this period approximately 75% of all trading in air carrier slots took place between airlines which had some sort of cooperative arrangement (Starkie (1992)).

<sup>27</sup> The introduction of the buy-sell rule coincided with a period when the US domestic airline industry was concentrating as a result of mergers and acquisitions.

<sup>28</sup> It is interesting to note that in the first three years approximately 15% of leased air carrier slots were leased to regional carriers which operated them using small turboprop commuter planes, preventing competitors from operating them using jet aircraft (Starkie (1992)).

it requires even though incumbents were allocated theirs free of charge. This also means that incumbents are initially given something of equal or near value to what they are after to trade with. Once again it is not necessarily the case that new entrants are more efficient than incumbent carriers; however, the buy-sell rule hinders the ability of any that are to enter.

Permitting slot leasing allows better utilisation of slots (particularly seasonal slots) and hence encourages efficiency while at the same time allowing a carrier to avoid having to surrender slots it is not currently using. It also makes it somewhat easier for incumbent carriers to expand their networks in response to customer demand than under the IATA system, as they can use slots leased to affiliated carriers<sup>29</sup>. However, they may only be able to expand their networks up to the point where they are fully utilising slots they were initially allocated and did not subsequently sell unless they sacrifice existing services, as they will face the same difficulties as new entrants in obtaining new slots. This is because all carriers always have to obtain new slots from other carriers.

The buy-sell rule is relatively immune to political intervention and has greatly relieved the administrative burden of the FAA, as its role in slot allocation at the four airports has been reduced to monitoring. However, the fact that all transactions occur among carriers (rather than the FAA) and that a substantial proportion of these are among affiliated carriers clouds allocation procedure transparency, and makes it prone to legal challenges.

## **Section II: Alternative Slot Allocation Methods**

The analysis in Section I suggests that optimally any method of allocating slots should be non-discriminatory, afford all parties national treatment and be transparent, and hence be immune to government intervention and (private) legal challenges. There are three ways of allocating slots which potentially meet all of these criteria.

### **Posted Runway-Use Prices**

One way of meeting all of these criteria may be to incorporate slot value into take-off and landing charges. Heathrow and Gatwick have gone somewhat towards doing this, by charging a premium for runway use at peak times of the day and during peak season<sup>30</sup>. However, at most airports take-off and landing charges are the same throughout the year, varying only by aircraft size. If airport authorities were to price take-off and landing slots at levels which incorporated their average value (as well as the average social cost of runway use<sup>31</sup>), excess demand for slots would be eliminated, and slots would be allocated to their most efficient users.

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<sup>29</sup> Most leases have tended to be for relatively short periods of time.

<sup>30</sup> These rates do not vary across aircraft size, and hence encourage the use of larger aircraft at these airports.

<sup>31</sup> Levine (1969) points out that currently take-off and landing charges generally reflect the marginal rather than the average cost of using air traffic control (ATC) services. In addition, they reflect the

Under this system the value of take-off and landing slots would be captured by airport-owners<sup>32</sup>. Regulations which currently set an upper limit on the profit margins airports may make from aircraft-related business would thus need to be relaxed. Regulatory authorities generally impose these limits on national airports and often insist that they be imposed on foreign airports<sup>33</sup> to prevent them from taking advantage of their market power by limiting capacity and extracting monopoly rents from airport users. Where airports are privately-owned, however, this system may make airport authorities reluctant to expand airport capacity: despite the increase in the number of aircraft movements per day, the lower charge per movement plus the cost of expanding capacity may mean that profits are higher when capacity is constrained.

The main problem with using posted take-off and landing charges to ration slot usage, however, is that this relies crucially on airport authorities' ability to determine market values and the average social cost of runway use at a given airport at each time of the day. In practice it is likely to be very difficult to perfectly price discriminate, given the uncertainty about the nature of market demand. Jones, Viehoff and Marks (1993) state that under such a system prices would be reset periodically on the basis of observed outcomes. For example, if there was excess demand for slots in a particular time interval in one period, prices would be adjusted upwards in the next period. It may take several periods, however, before the "correct" prices are set, such that scarce resources are wasted (if prices are set too high) or excess demand remains (if prices are set too low) in the meantime. Indeed, prices which equate demand and supply in every time interval may never be met, given that demand for different types of air transport services will grow at different rates over time.

### **Lottery + After-market**

An alternative method of allocating slots which potentially meets the criteria set out above is to use a lottery to initially randomly allocate slots, and then permit post-allocation trading among lottery-participants.

There are, however, several disadvantages to using lotteries as a method of slot allocation. The main disadvantage is that it is highly likely that carriers will be allocated non-efficient if not non-workable combinations of slots in the initial lottery. The more inefficient the initial allocation, the greater the extent of trading carriers will need to undertake in the after-market in order to obtain efficient allocations. When licences to operate radio spectrum were allocated by lottery in the US, for example, it took over two years for secondary-market trading of licenses to cease. This not only imposes costs on participants, but also can delay the implementation of services

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(marginal) private cost of runway use, rather than the (average) social cost, as they do not incorporate the costs of aircraft "footprint" pressure (runway wear-and-tear), noise or pollution.

<sup>32</sup> Airport-owners would capture an amount equal to the valuation of the second-highest bidder for each slot; successful bidders would capture the difference between their valuation and the amount they paid for each slot (the second-highest bid).

<sup>33</sup> This is done by including a clause regarding airport pricing in agreements governing trade in air transport services. Article 10.3 of the US-UK ASA (Bermuda II), for example, states that airport charges "... may reflect, but shall not exceed, the full cost... of providing appropriate airport and air navigation facilities, and may provide for a reasonable rate of return on assets, after depreciation." (Jones, Viehoff and Marks (1993): 54).

associated with the use of the slots, causing carriers to forego revenue and imposing huge costs on passengers and communities which rely on the provision of air transport services. These costs will be even larger if individual lotteries are held for each airport, each of which only covers the slots available at this airport, and these are conducted sequentially. The efficiency of the process can be maximised by imposing eligibility requirements (such as requiring potential lottery participants to register and show that they are able to operate the slots should they be allocated them) as these will minimise speculative behaviour<sup>34</sup>; however, these have to be of form which does not deter genuine participation.

Carriers will also encounter similar problems in the secondary market as US carriers currently do under the buy-sell rule, as they must obtain slots from lottery-winners, many of whom will be potential competitors. Carriers may tend to lease slots for short periods of time rather than sell them outright, and only lease them to carriers with whom they have established cooperative agreements. If the lottery is once-off, carriers may experience difficulties adjusting their slots portfolios or acquiring additional slots in the future, preventing them from fully responding to changes in consumer demand. It is thus not necessarily the case that secondary market trading will ever enable carriers to obtain efficient slot allocations. Trading in the secondary market will thus be non-transparent and subject to legal challenges.

This process will be unpopular with some incumbent carriers, especially the less slots which are grand-fathered and the more are allocated by lottery, as it is likely that they will be forced to engage in secondary market trading in order to obtain the slots they require, and, if successful, they will be required to pay these slots. However, it may also be unpopular with the general public, as this method of slot allocation allows the value of a scarce public resource to be captured entirely by lottery winners. The government is missing out on a windfall revenue gain which could be used to improve the budget bottom line and bring relief to tax-payers. In the radio spectrum lotteries the US Government was severely criticised for giving away this revenue when it became public knowledge the sums of money licences were being bought and sold for in secondary markets.

### Auctions

A third method of allocating slots is to use an auction process. Carriers would submit bids to a competition or air transport regulatory authority, and slots would be allocated to those with the highest bids. Carriers would thus be forced to pay market prices for all slots they require. Secondary market trading would be permitted to allow carriers to make minor adjustments to their slot portfolios in response to information which becomes available after the initial auction.

The US Federal Communications Commission (FCC) has held auctions on sixteen occasions since July 1994 to allocate almost 6000 radio spectrum licences for use in nine different wireless and satellite categories. These auctions have been highly successful, and the FCC now has a fully computerised Automated Auction System (AAS) which it uses to determine the revenue-maximising configuration of bids. In

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<sup>34</sup> In the US radio spectrum lotteries, it took 20 months to screen potential lottery participants; however, when pre-lottery screening was abandoned the lotteries attracted approximately 400,000 speculative participants hoping to acquire a license to sell on.



addition, the task of allocating radio spectrum is in many ways similar to the task of allocating take-off and landing slots, given their similar characteristics.

As in the case of take-off and landing slots, radio spectrum had previously been allocated via administrative decisions<sup>35</sup>. This was becoming increasingly complex and time-consuming to all involved, however, as the advent of new communications technologies and services increased the demand for spectrum. To relieve its administrative burden the FCC then used lotteries. However, as already mentioned it took some years before after-market trading resulted in the licences being allocated to those even capable of and intending to providing telecommunications services, and the US Government was severely criticised for “throwing away” windfall revenue.

The auction format used was a simultaneous, multi-round sealed-bid auction. A simultaneous format was used because spectrum licence values are to some extent interdependent: the value of a particular licence will depend on the value of others. They thus allow prices of similar items to equalise. Multiple rounds of bidding were conducted for two reasons. Firstly, it was thought that there was a great deal of uncertainty among bidders about market demand and hence the underlying value of the licences, that is, that common value uncertainty was high. A multi-round format would enable bidders to observe the bidding behaviour of their competitors, and hence learn more about the true value of licences in successive rounds. This, in turn, would reduce the risk of the “winner’s curse”: that the bidder winning the auction for a particular licence is the one who overestimates common value the most, and hence is not necessarily the most efficient user. Common value uncertainty also reduces revenues to the auctioneer, as the optimal bidding strategy for each bidder is to reduce their bids. Secondly, a multiple-round format enables auction participants to fully respond to price information obtained in later rounds. If bidding for a particular licence goes above the constraints of their budget, they can switch to bidding for a different licence. This type of auction thus reduces the risk that bidders are unable to respond to price information which becomes available and, given their budget constraints, miss out on obtaining licences entirely. Bids were required to be sealed to minimise the risk of collusion among auction participants; auction participants were assigned bidder numbers. However, after several rounds participants were generally able to match bidder numbers with names from bidding behaviour given a priori information about each bidder<sup>36</sup>.

Similar auction formats had been used to allocate radio spectrum in other countries prior to 1994. These have been conducted with varying degrees of success; however where they have been unsuccessful it is generally due to flaws in the design of the auction, rather than a failure of the actual auction mechanism itself. In New Zealand, for example, a series of second-price sealed-bid auctions were used to allocate radio spectrum in the early 1990s. The auctions successfully allocated spectrum to those bidders who valued it most; however, the lack of a floor price for bids together with thin demand and large divergences in valuations among bidders meant that many winners ended up having to pay only a small proportion of their

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<sup>35</sup> The FCC held quasi-judicial comparative hearings when there were two or more applicants.

<sup>36</sup> Given this and the fact that, in its assessment, the likelihood of collusion among auction-participants is low, the FCC has decided that bids will be open in future auctions (Cramton (1995)).

willingness to pay<sup>37</sup>, which created much political controversy. Establishing reserve prices would have achieved the same allocation of spectrum among bidders but increased revenues accruing to the Government. In Australia, a first-price sealed-bid auction was held in 1993 to allocate two satellite television licences. Once again the auction successfully allocated the licences efficiently; however, achieving this took almost a year due to the lack of penalties for default<sup>38</sup>. Implementation of the services associated with the licences was thus delayed by almost a year.

Take-off and landing slots are similar to radio spectrum in a number of ways. Firstly, slot values are highly interdependent: the value of a particular slot to a carrier will depend crucially on what other slots the carrier acquires. Secondly, there is likely to be a great deal of uncertainty among carriers about market demand and hence underlying slot value. In addition, uncertainty about a particular market is likely to be greater among those carriers which do not currently serve that market. Furthermore, carriers already serving those markets will have an incentive to bid for the necessary slots given the investments they have made in difficult-to-transfer assets associated with the provision of these services. A multi-round format would reveal each bidder's private valuations of slots through successive rounds of bidding activity, mitigating uncertainty about underlying market demand and redressing the imbalance in the information set available to incumbents and new entrants respectively<sup>39</sup>. It would also enable auction participants to fully respond to price information obtained in later rounds, reducing the risk that they are left with inefficient and unworkable combinations of slots. Sealed bidding is likely to be more necessary in slot auctions given the increasing number of cooperative agreements among carriers. Open bidding would make it easier for carriers to collude with their regional affiliates or global alliance partners.

This suggests that simultaneous, multi-round, sealed-bid auctions (together with an after-market to permit minor adjustments) could possibly be used to allocate take-off and landing slots. However, there are several important ways in which the slot allocation problem differs from problem of how to allocate radio spectrum.

### **Section III: Adapting the Spectrum Allocation Mechanism to Auction Slots**

#### **Combinatorial Bids**

Firstly, while there is perhaps little synergy value inherent in operating particular combinations of spectrum licences together, this is not the case for take-off and landing slots. A certain combination of slots may enable a carrier to operate a high frequency service on a particular route, for example, such that it is able to capture economies of traffic density. If carriers can only bid for individual slots, they

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<sup>37</sup> In one case a firm bidding \$NZ 7m ended up paying only \$5000, while another bidding \$100 000 paid only \$6.

<sup>38</sup> Two bidders with no intention of launching services put in a range of bids which ensured that they won the auction; they then proceeded to default on successive bids while seeking profitable resale opportunities.

<sup>39</sup> An activity rule would need to be imposed which requires auction participants to increase their bids by a minimum percentage each round (which would be lowered as bidding activity slows) in order to prevent carriers from concealing their true valuations until the final round.

will have to decide how to spread this synergy value across their bids for the individual slots which make up such combinations. This creates the risk that a carrier may spread the synergy value in such a way that it is outbid on a particular slot and hence is left with a combination of slots which has a lower overall value than what it paid for them. In addition, this combination of slots may be unworkable.

One way to avoid this problem is to permit carriers to submit *combinatorial* bids as well as bids for single slots. A combinatorial bid would be successful if the price offered for a group of slots was more than the sum of the highest bids offered for each of the slots individually. However, permitting combinatorial bidding may actually produce some inefficiencies due to free-rider problems. Two bidders each bidding for a single slot may have a combined valuation for the two slots which is higher than that of a bidder which submits a single bid for both slots, but the combinatorial bid may win as each of the bidders after a single slot has the incentive to let the other raise the bid. In addition, combinatorial auctions are difficult to conduct in practice, due the complexity of determining the revenue-maximising configuration of bids, particularly when there are many items being auctioned as would be the case in slot auctions. However, given that the FCC has been instructed to experiment with combinatorial bidding and hence that combinatorial bidding may be permitted in future spectrum auctions, it is possible that software capable of running such auctions will soon be available.

### **Contingency Bids**

The second way in which the task of allocating slots differs from the problem of allocating radio spectrum is that slots within a particular time-period are substitutes for one another. The longer the length of the route a carrier plans to use particular slots for, the greater this time period will be. Any slot auction will thus also need to permit *contingency* bids. These will allow a carrier which wants to obtain a group of slots sometime within a particular time interval to submit multiple bids for this group which differ by time or other factors, but only be allocated at most one group of slots.

Allowing carriers to submit contingency bids increases the complexity of determining the solution to the slot allocation problem. Jones, Viehoff and Marks (1993) also question whether carriers would be able to determine all the bids they could possibly submit, given that each service could potentially vary by departure time, aircraft size, and so on. The set of all possible bids could be so large that it is too time-consuming to determine; however, if all the alternatives are not considered and bid for, they may miss out altogether<sup>40</sup>.

A further problem with combinatorial auctions which permit contingency bidding is that no set of prices can be determined which will separate bids that are chosen from those that are not because this is a discrete programming problem. Only a lower price below which no bids are accepted and an upper price above which all bids are accepted can be determined. Which of the bids lying in the region between these two prices (the “core” region) will be accepted and which rejected will be determined by the exact requirements of each bidding airline. Those carriers whose services “fit in” will be allowed to operate services at a particular time slot, even

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<sup>40</sup> Jones, Viehoff and Marks (1993); 47

though the bids of others whose services do not fit in may be marginally higher. In practice, then, some administrative assistance may be required to determine which of the services whose bids lie in the core region will fit in and hence be allocated the required slots. The decisions of these administrators will need to be transparent, non-discriminatory, and consistent with national treatment for the outcome to be efficient. However, bids lying in the core region comprise a small percentage of all bids and are known to decrease in relative number as the problem size increases<sup>41</sup>.

Rassenti, Smith and Bulfin (1982) conducted controlled experiments in which six participants were required to determine and bid for combinations of slots available at six hypothetical airports. Each experiment consisted of sequence of market periods conducted within a three hour time limit. In each period bids submitted were entered into a computer which subsequently determined the revenue-maximising combination of bids and hence the auction solution. Those participants submitting the bids which maximised system revenue paid a price equal to the sum of the marginal (shadow) prices (the lower bound prices) of each of the slots in the combination bid for, and hence were able to fully capture the synergy value inherent in each slot combination. This charging system was adopted to encourage demand revelation: the optimal bidding strategy under such conditions is to bid truthfully<sup>42</sup>. Participants could then trade slots in an after-market of the oral-bid type.

Despite the potential problems associated with the existence of a core region of bids, the experiments were highly successful: experienced participants achieved allocative efficiencies of 98-99% of the possible surplus after only a few time periods. This was achieved despite the fact that inexperienced participants repeatedly tried to engage in speculative behaviour early on. Efficiency improved over time in each experiment, suggesting that learning effects were significant. Post-auction trading was minimal and decreased over time, despite the potential for each participant to engage in speculative behaviour. Indeed, such behaviour decreased over time due to the difficulty of obtaining the additional slots required to make-up a particular combination or off-loading unwanted slots in the secondary market. Furthermore, auction performance did not seem to deteriorate as the complexity of formulating combinations increased. The auction thus appears to minimise the extent to which it is necessary to engage in secondary market trading, which is what we would want it to do in practice given the difficulties inherent in trading with potential competitors and the cost involved in such transactions.

### **International Cooperation**

The third way in which the slot allocation problem differs from the task of allocating radio spectrum is that slots at multiple airports located in many different countries would need to be auctioned simultaneously. Computer software and communications technology, however, make this task relatively easy. Carriers and communities could simultaneously submit bids from all over the world via telephone or the Internet and monitor auction progress on the Internet. The FCC's AAS could be

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<sup>41</sup> Rassenti, Smith and Bulfin (1982): 406

<sup>42</sup> If participants were forced to pay the amount they bid in the auctions, they would have tended to bid less than their true valuation of the slots. They would do this to minimise the price they would have to pay should they be successful while at the same time ensuring that the probability of success remained high.

adapted for slot allocation, significantly reducing the once-off cost associated with auction design. However, even if new software had to be developed, its total cost is likely to be equivalent to only a small proportion of the total revenue generated from the auctions<sup>43</sup>.

Decisions would need to be made as to who would fund the costs associated with the development of the necessary software and the running of the auctions, and who would actually conduct the auctions. The US may be unwilling to hand over the software it has developed for auctioning radio spectrum, or indeed to adapt this for slot auctions, without financial compensation; some sort of joint-venture-type agreement may need to be established, whereby several countries fund the development of the slot auction software. Auctions would presumably need to be run by a national competition authority, such as the US Department of Justice (DoJ), under the oversight of competition authorities of other countries.

What is likely to be more difficult is gaining the necessary approval and funding to implement a slot allocation system based on auctions worldwide. Even implementing it initially only in the regions providing the majority of the world's air transport services would require the agreement of many countries. Despite the benefits inherent in switching to an auction system, it is possible that incumbent carriers will oppose its introduction given that current ways in which slots are allocated protect them from significant new entry, provide them with substantial certainty over their future operations, and do not force them to pay for the majority of slots they use. Historically incumbents have been extremely effective lobbyists, given that they are generally large employers and given their importance to the business community and the travel industry, and hence their importance to the economy as a whole.

New entrants may also be unsupportive of a system which forces them to pay for slot usage, despite the fact that it also forces incumbents to pay and requires all carriers to deal with a neutral seller to obtain slots. Indeed, it is commonly claimed that new entrants will be unable to compete with larger, more established carriers in slot auctions, given incumbents' access to large financial reserves. This is somewhat misleading, however, in two ways. Firstly, in bidding for particular slots it is not just the absolute amount bid relative to competitors which a carrier takes into account, but also the difference between the profit it expects to make from operating those slots if it is allocated them and their cost. For an incumbent to outbid a new entrant it must thus not only bid a higher amount, but also still be making a profit at this level. If a new entrant has relatively lower costs such that its expected profit margin is greater than the profit margin the incumbent anticipates, it will have greater bidding leverage against the incumbent. Secondly, in practice, new entrants tend to be carriers established by successful entrepreneurs backed up by business empires and/or financial institutions given the substantial costs involved in setting up an airline<sup>44</sup>. They thus also generally have access to substantial funds and good credit-ratings with major financial institutions.

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<sup>43</sup> The total cost of all FCC auctions to September 1997, including the costs involved in running the auctions, was SUS 74 million, which is equivalent to only 0.62% of total auction revenues raised.

<sup>44</sup> Examples include Virgin Atlantic Airways (the Virgin Group) and Eva Air (Evergreen shipping).

Both incumbent and new entrant-carrier objections to the implementation of an auction system may decrease over time, however, given that demand for air transport services is predicted to continue growing at high rates and hence airport constraints are likely to worsen. It may also be possible to gain support for a slot auction system in world trade negotiations if air transport issues are negotiated together with issues affecting other sectors, as any concessions granted which relate to air transport can be balanced by benefits gained in other areas. In addition, particularly in the US, consumers groups wanting lower airfares and communities wanting more flights into particular regions regardless of the nationality of the carrier providing them are becoming more visible and hence are having greater influence in government decisions.

### **Division of Auction Revenue**

The fourth way in which slot auctions would differ from the US radio spectrum auctions is that auction revenue would need to be divided among many countries, given that the auction involves slots at airports located all over the world. Presumably the revenue raised from the auction of slots located at a particular airport would go to the government of the country in which that airport is located, given that governments generally hold proprietary rights over the slots available at airports located within their borders. If carriers are permitted to fully capture the synergy value inherent in particular combinations of slots as in the Rassenti, Smith and Bulfin (1982) experiments, governments will only receive an amount equal to the sum of the marginal prices of each of the slots available at the airports located within their borders. However, this is not likely to be controversial given that revenue maximisation is not the primary objective of governments in the slot auctions.

Importantly, governments must announce what they intend to use the revenue accruing to them from the slot auctions for before the auctions take place, such that this information can be incorporated into bids. Governments may, for example, decide to use it to expand airport capacity. If this is the case, the present value of the future profits of carriers holding slots at those airports will decrease, constraining carriers' budgets and hence the maximum amount they will bid in the auctions. Alternatively, they may decide to use it to improve national accounts, and subsequently lower corporate tax rates. In this case carriers serving airports located in countries where this occurs will expect their future profits to be higher and adjust their bids upwards.

### **Slot Validity**

The fifth way in which slot auctions would need to differ from the radio spectrum auctions is in terms of the length of time the rights allocated are valid. Spectrum licences are allocated for ten years; however, they are typically renewed for a negligible charge provided certain requirements are met and hence are virtually valid in perpetuity. If this was also the case for auctioned slots, even if after-market trading was permitted, carriers would have difficulty accessing slots after the auctions as slot suppliers would also be potential competitors. As already discussed, carriers will thus find it difficult to expand their services in line with consumer demand.

Slot rights should therefore probably be granted for a fixed length of time only, and the more rapidly air transport markets are changing, the shorter this length

of time should be. This time-period should be sufficiently long, however, to give auction winners the incentive to make sunk investments in the route. This must also be determined and announced before any auctions take place to enable auction-participants to incorporate this information in their bids.

#### **Section IV: Incorporating Route Rights in Slot Definition**

The final way in which slot auctions would differ from the radio spectrum auctions is in terms of what is being auctioned. Auctions of radio spectrum embody the right to provide services which require spectrum as well as the spectrum itself. Slot auctions, however, would only provide auction-winners with the ability to take-off or land at a particular airport at a particular time. The routes carriers can serve using the slots allocated to them are currently determined by the terms of bilateral agreements and the decisions of national regulatory authorities responsible for allocating negotiated increases in capacity.

Under the EEA CAM agreement, carriers registered in any of the signatory countries have the rights to automatically begin operating new services within the EEA or increase capacity on routes already served. Similarly, in markets governed by liberalised bilateral agreements, signatory country carriers can automatically begin operating new services between the two countries or increase flight frequency on existing routes. In practice, however, whether or not they will add flights will depend on whether they can obtain the slots required to provide the service, or, where airports are severely constrained, whether they are prepared to sacrifice existing services and use those slots. In markets governed by ASAs, however, any negotiated capacity increases must be allocated among national carriers.

In countries which have a single flag-carrier allocation is automatic. In countries which have multiple national carriers providing international services, however, regulatory authorities must decide how capacity should be allocated among them. Capacity has been allocated in different ways. Historically Canada had a "Division of the World" (DOW) policy whereby international capacity was automatically assigned to the national carrier which had the rights to serve that region. The right themselves had been pre-allocated by regulatory authorities. The lack of overlap of the rights granted to Air Canada and Canadian Airlines respectively, however, limited each carrier's exposure to competition on international routes<sup>45</sup>. The Republic of Korea uses a system based on route traffic thresholds whereby new entry by a national carrier (Asiana) is permitted on a route if annual traffic levels exceed a certain level predetermined by national regulatory authorities<sup>46</sup>. Given that these threshold levels are known, the incumbent carrier (Korean Air) is able to limit competition by keeping annual traffic loads just below them. In the US the FAA holds quasi-judicial hearings to determine which of the competing carriers most closely satisfies predetermined criteria and hence should be allocated the capacity<sup>47</sup>. In the EEA national regulatory authorities allocate negotiated increases in capacity in non-

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<sup>45</sup> For details see Oum (1995); 96-97.

<sup>46</sup> For further details see Kim (1997).

<sup>47</sup> See the US DoT Office of the Secretary website (<http://www.dot.gov/general/orders>) for transcripts of capacity allocation decisions.

intra-EEA markets among their national carriers. In the UK, for example, the UK Civil Aviation Authority (CAA) uses quasi-judicial hearings to allocate increases in capacity in these markets.

Given that it is not necessarily the case that the carriers which have been allocated the rights to serve particular markets will be the most efficient providers of services in those markets, the pool of carriers bidding for particular slots at each airport will not necessarily be the most efficient users of those slots. Indeed, generally the lower the number of carriers with rights to serve particular markets, the lower the probability that any slot auction outcome will be efficient. Allocating route rights efficiently will also not necessarily ensure that the auction outcome is optimal, as these routes have been pre-specified by aviation regulatory authorities. It is possible that rights currently available do not cover all the segment combinations carriers would choose to fly if current foreign investment restrictions (and hence mode of supply restrictions) were removed.

One way of ensuring that *service* rights and hence slots are allocated efficiently is to incorporate the right to provide services in slot definition. Slots would then embody both the right to provide services and the ability to physically commence or terminate a service. As well as enabling carriers to determine their own segment combinations and the level of capacity to provide on each of these, this would turn what is now a two-step process into a single step.

Consolidating these two steps would require all countries to remove the restrictions on capacity and foreign investment inherent in agreements they have concluded which govern trade in air transport services, which would essentially mean the end of all such agreements. Opposition to such moves is likely to be strong. However, the conclusion of liberalised bilateral agreements show that it is not impossible to remove capacity restrictions on a reciprocal basis. Similarly, the establishment of the EEA CAM shows that restrictions on foreign investment can be reciprocally removed. The conclusion of the GATS in the Uruguay Round of world trade negotiations also suggests that air transport services trade may not always be exempt from the rules of the world trading system.

In theory, such a system would open-up bidding for all slots to all carriers. However, in practice the number of carriers bidding for particular slots will be determined by passenger demand and the costs of providing services in particular markets. While it may be possible for a particular carrier to provide services between two particular cities, they may not bid for the slots which would enable them to operate such services as they would be unable to make a profit on these. This may be because demand for such services is low, or because the service does not connect with their existing network; studies have shown that economies of scale are negligible or even negative in the provision of air transport services in the sense that adding a non-contiguous route to a carrier's network does not reduce its average costs. It is thus highly likely that, at least initially, the number of carriers bidding for slots at each airport will not be much higher than the number which currently apply for slots at these airports under the IATA system or the buy-sell rule. In the longer-term these numbers may increase as carriers' networks expand in line with traffic increases and the financial resources available to each increases.



## Summary and Conclusions

In summary, it may be useful to re-examine the feasibility of using auctions to allocate take-off and landing slots at the world's major airports in light of the highly successful auctions of radio spectrum in the US. Given the similarities between the tasks of allocating spectrum and the slot allocation problem, it is possible that we are not too far away from developing the software required to handle slot auctions. The results of the controlled experiments reported in Rassenti, Smith and Bulfin (1982) show that it is possible to achieve extremely high levels of efficiency in slot auctions which permit combinatorial and contingency bidding despite the potential problems associated with the existence of the core region. Such auctions appear to require secondary market trading only to correct (marginal) misallocations and to permit adjustments in response to information not available at the time of the auctions, and hence avoid the problems generally associated with secondary markets such as being forced to try to obtain slots from potential competitors. However, further experimentation with combinatorial bidding will be required to determine the effects of the free-rider problem on auction efficiency.

Perhaps the biggest hurdle to moving to auction-based slot allocation system and ensuring that its outcomes are fully efficient will be obtaining the approval of the many countries in which the world's major airports are located. Their approval will be required to remove the IATA system and the buy-sell rule, as well as the capacity and foreign investment restrictions contained in the agreements which currently govern trade in air transport services. Multilateral cooperation will also be required to develop the necessary software and to run and monitor the auctions. Agreement may be more forthcoming over time, however, as airports become increasingly constrained, and as more of air transport services trade becomes governed by agreements with liberal capacity and foreign investment provisions. Increasing jurisdiction of the GATS over world services trade will also put pressure on countries to agree.

Whether or not auction outcomes are efficient in practice will also depend on the extent to which carriers have competitive access to other facilities essential to the provision of air transport services, such as airport infrastructure and services and ticket sales channels. If particular carriers anticipate problems accessing these facilities at competitive prices in relation to providing services to particular destinations, they will scale down their bids for slots at the associated airports. It will thus be useful in future studies to examine ways in which the problem of accessing these facilities on competitive terms can be addressed. It may also be useful to examine whether there are complementarities between slots and some of these facilities, such as terminal gates and ground-handling services, in order to determine whether or not slots should be auctioned jointly with other facilities.

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## Regulation as a driver for international airline alliances

Hannu Seristö

### ABSTRACT

There is an apparent strong need to consolidate the airline industry of the world. However, there have been few mergers and acquisitions in the industry; particularly international mergers and acquisitions are almost non-existent. Airlines have used other ways than mergers and acquisitions, primarily alliances, in their search for more competitiveness. Evidently much due to government control airlines can go only so far in trying to rationalise and consolidate the industry and they appear rather frustrated by the fact that the natural evolution towards transnational companies in the industry is effectively blocked.

So, the airline industry is a major theatre for alliances. Many reasons for alliances have been suggested, such as the seek for more market presence and lower costs; the role of authority intervention in the industry restructuring has been often noted, too. However, it appears that there are no clear frameworks for assessing alliances in the framework of airline strategies – covering the drivers or motives and objectives of alliances. Consequently, this study will focus on the international alliances in the airline industry, and sets out to seek answers to the following questions:

- what are the drivers of international airline alliances?
- what are the objectives of international alliances?
- what is the role of government or other authority regulation in the alliance formation within the airline industry?

The objective of this study is to present a framework depicting drivers and key variables of international airline alliances, particularly the authority regulation, in the framework of airline strategies. The core of the study is a longitudinal analysis of the alliances reported in the industry, using firms' own and third party material as sources of information. Key sources of information are annual reports between 1988 to 1998 from thirteen major airlines from Europe, North America and Asia.

As to the findings, among the three key alliance motivators it appears that it is the pursuit of stronger market presence that clearly has been more apparent and dominant, the need for better resource utilisation being clearly secondary and also more of a longer-term nature. Concerning the role of regulation and the need to circumvent it, the assessment is somewhat difficult. It seems very often to be a fundamental factor, but very rarely is it expressed as the primary reason - it could be seen a relevant, compelling factor for nearly all airlines of the world, as alliances appear the only feasible way to grow and seek presence in a larger market. There are differences between airlines from North America and Europe, as well as between large and small carriers, concerning whether they see alliances primarily as offensive or defensive moves.

The paper presents a framework where drivers, or motives, and objectives for airline alliances are presented in a corporate strategy setting; special emphasis is on the role of regulation. Also airlines of different size are positioned along the offensive-defensive dimension of alliance objectives.

Key words: international airline alliances, motives and objectives, regulation.

# **Regulation as a driver for international airline alliances**

**Hannu Seristö**

## **INTRODUCTION**

The growth of alliances in the 1990's has been rather phenomenal; studies suggest annual growth rates above 100 per cent in the number of business alliances (see e.g. Pekar & Allio 1994, Luo 1996). Strategic alliances have been found to be unstable and they generally speaking have a poor record of success (see e.g. Gant 1995, Brouthers et al. 1995). Strategic alliances have been studied from various perspectives - e.g. that of alliances characteristics (Borys and Jemison 1989), complexity of alliances (Killing 1988), rationale of alliances (Contractor and Lorange 1988), transaction costs (Parkhe 1993), alliances between competitors (Hamel, Doz and Prahalad 1989), trust and contractual arrangements in alliances (Gulati 1995), learning from alliances (Parkhe 1991; Lei et al. 1997; Inkpen 1998), value creation through alliances (Chan et al. 1997; Doz and Hamel 1998), and the assessment of alliance performance (Dussauge and Garrette 1995; Gleister and Buckley 1998).

The airline industry is a major theatre for alliances. Airline alliances have been studied, for example, from the perspective of benefits (see Park and Zhang 1997), performance enhancement (Park and Cho 1997), corporate value (Park and Zhang 1998), critical success factors (Bissessur 1996) and safety implications (Button 1997). Many reasons for alliances have been suggested, such as the seek for more market presence and lower costs. Also the role of authority intervention in the industry restructuring has been often noted as one contributing factor to the popularity of alliances recently. However, it appears that there are no clear frameworks for assessing the relationship between airlines' strategies and the alliances – including the drivers or motives and objectives of alliances. Consequently, this study will focus on the international alliances in the airline industry, and sets out to seek answers to the following questions:

- what are the drivers of international airline alliances?
- what are the objectives of international alliances?
- what is the role of government or other authority regulation in the alliance formation within the airline industry?

## **A brief history of airline alliances**

The world airline industry has seen very strong growth during the last decades. For example, the volume of scheduled services, measured in the number of passenger-kilometres flown, more than doubled from 1980 to 1995. As for the future, most forecasters see an annual growth rate of traffic volume in the region of 4 - 5 per cent, meaning that the traffic volumes would again double in about 15 years.

The airline industry has experienced major changes in the operational environment during the last two decades. Liberalisation, or deregulation, has changed the rules of competition drastically in most major markets of the world. The industry experienced a severe recession in the early 1990's, sparked by the Persian Gulf crisis, but with the recovery of major economies and the very strong growth in air transport demand it has

improved performance significantly towards the end of the decade. In fact, in 1997 the 100 largest airlines of the world had a combined sales of USD 288 billion, operating profit of 18.6 billion, and net profit of 9.5 billion. In 1992, the worst financial year of the industry history, the corresponding net result was a loss of USD 8 billion. Still, the financial performance leaves room for improvement - the net margin for the top-100 carriers in 1997 was only 3.3 per cent (Gallacher 1998).

A great majority of the existing alliances in the airline industry have been formed in the 1990's, but there are alliances the origins of which can be traced as far back as to the 1940's. For example Air France has helped to set up the operations of many African airlines - such as Air Afrique, Royal Air Maroc and Tunisair - and still have equity stakes in those carriers. Similarly, Iberia invested already in 1948 in Aviaco in South America. National interests and governments played a key role in these early alliances. There was quite little alliance activity until the late-1980's when a number of equity-based arrangements took place. It was the Scandinavian SAS which really started to proactively seek alliances, perhaps with a more strategy-level approach than what had been done until then by other airlines. SAS worked on many equity-based schemes, and had some success but some failures, too.

In the 1990's the number of alliances has steadily grown each year, and the scene has become very unstable. For the sake of comparison, in 1990 the industry sources listed 172 alliances, out of which 82 involved equity investment (Airline Business 1990). The latest survey by Air Transport Intelligence (1998) reported that there were a total of 502 airline alliances in mid-1998, with an increase of 38 per cent over the year 1997 - these alliances were formed among 196 airlines. Most airline alliances are between two partners, but recently arrangements of more than two participants have emerged. World airlines are in the process of forming groups in their preparation for harder global competition - the largest groups *Star Alliance* and *oneworld* now have each about 20 per cent of the world international passenger markets. Most alliances are between airlines from different countries, but there are alliances between carriers of the same nationality, too. Most airlines have several alliances, including domestic and international alliances - the largest number of alliances in 1998 was by Air France with 28 arrangements, out of which all but one were with foreign partners.

Out of the total of 502 alliances in 1998 only 56 (11%) involved equity; government authorities play a key role in determining the conditions for equity-based arrangements. The role of government or other authority regulation, or other type of intervention, in the airline partnerships deserves a closer look.

#### **On the nature of airline alliances**

There have been very few mergers and acquisitions in the world airline industry as a whole. There was quite a lot of M&A activity in the United States in the 1980's, but overall, particularly international mergers and acquisitions are almost non-existent. The reason for this is the prohibitive stand by regulatory authorities world-wide. Consequently airlines have been forced to use other ways than mergers and acquisitions in their search for more competitiveness. There is a strong need to consolidate the industry, but evidently much due to government control airlines can go only so far in trying to rationalise and consolidate the industry.

Rhoades and Lush (1997) have suggested two dimensions on which alliance arrangements differ, namely commitment of resources and complexity of arrangement. Partly following that division, alliances can be put into three categories based on the extent of co-operation: simple operative route-based alliances, broader marketing alliances, and equity-based alliances. There are various reasons why an airline forms alliances with other airlines. Usually these reasons are linked to the strive for more competitiveness on the global market, for which airlines have used a number of different co-operative arrangements. Joint ground handling, co-ordination of schedules, joint flight operations, swap of flying personnel, sales and purchases of block space on aircraft, code-sharing and equity investments in another airline are some of the co-operative ways used.

As mentioned, the airline industry has been very tightly regulated for most of its history. Liberalisation really started only in 1978 with the US airline industry deregulation. Even after the European Union reached the final stage of its airline industry liberalisation in 1997 there are many types of regulations and limitations that government authorities set on airline operations and competition. In fact the situation has reached a somewhat schizophrenic point: on the one hand authorities press for more competition through less regulation, but on the other hand, when stronger airlines try to rationalise operations in the name of better competitiveness, then authorities intervene and set limits on or even deny such efforts. It seems that fair play is sought, but not too fair. Consequently it is the authorities, primarily those of the United States and the European Union, that may decide whether the airline industry can develop into one of efficient global players, global quality service and, perhaps, low fares for consumers.

### **Challenges and open questions**

Airline alliances, just like strategic alliances in most other industries, have had a rather poor record of success. It has been suggested that fewer than 30 per cent of international alliances in the airline industry have been successful (Lindqvist 1996).

Simply put, airlines seek international competitiveness through alliances. Even if in general it is the economies - be that of scale, scope or density - that motivate airlines, it is not necessarily completely clear what are the different types of drivers that are behind alliance formation. Also, the consequent objectives of alliances are not always clear. Moreover, the particular role of authority regulation in alliance formation is often unclear.

As suggested by earlier research, there are drivers of different level for international airline alliances. Some alliances are driven by mere cost savings in operations, like through rationalising ground handling at airports operated by both or all partners. Others are more of a market power issue, for example through code-sharing and pooled frequent flyer programs. Yet others may be more of a strategic nature, aiming for example at the mere survival of the airline. Concerning the objectives of international airline alliances, the immediate objectives can naturally be drawn from the drivers; so, the objective of a block seat arrangement with another airline would be to secure or increase sales. However, the longer-term strategic level objectives of, say,

growth, market expansion, image enhancement, learning, and so on are seldom crystal clear.

The objective of this study is to suggest a model which depicts drivers and key variables of international airline alliances, particularly the authority regulation, in the framework of airline strategies. The study bases on prior research on competition in the airline industry and on strategic alliances. The core of the study is a longitudinal analysis of the alliances reported in the industry, using firms' own and third party material as sources of information. Key sources of information are annual reports between 1988 to 1998 from the following airlines: Air Canada, American Airlines, British Airways, Canadian Airlines (PWA Corp.), Delta Air Lines, Finnair, KLM, Lufthansa, Qantas Airways, SAS, Swissair, Thai Airways International, and United Airlines.

### **SPECIAL FEATURES OF THE AIRLINE INDUSTRY**

The airline industry is in many ways one of the most international of service industries. International traffic forms a major portion of all air traffic, and even domestic traffic is most often dependent on or at least tightly linked to international services. Then, do multinational enterprises dominate in this very much international business, like they do in most other industries?

In this very much international business there are no dominant, truly global players. A question has often been asked whether there are true multinational companies (MNC) among airlines. By definition MNCs should conform to the criteria (see Bartlett and Ghoshal, 1995) of, first, having substantial direct investments in foreign countries. Second, they should be engaged in the active management of the offshore assets, rather than simply hold them in a passive portfolio. The management criteria would appear to be fulfilled by most internationally operating carriers. However, concerning investments, airlines rarely have significant tangible investment in foreign countries, but typically hold only rather small marketing subsidiaries abroad. In addition some larger carriers own partly or wholly smaller carriers that operate in foreign countries. The investment criteria comes into an interesting light when one considers that the key production machinery, the aircraft, are in fact assets that move at the speed of some 800 kilometres per hour from one country to another - so even if each aircraft is always registered in a certain country the determination of where the production machinery really is located may be somewhat indefinite. However, as Bartlett and Ghoshal (1995) define the investments not only as production facilities but also as financial, legal and contractual relationships with foreign affiliates - in addition they emphasise the management integration of operations in different countries as the key differentiating characteristic of an MNC - it is fair to say that many internationally operating large airlines are MNCs. Then, whether airlines are transnational companies can be questioned, too. The term transnational has often been used rather loosely, but the more specific definition of the term used by Bartlett and Ghoshal refers to firms being locally responsive in various national markets while retaining their global efficiency. This definition suggests specialised but dispersed resources and activities, realised in the form of interdependent network of world-wide operation, producing both efficiency and flexibility at the same time. Now, whether airlines operate as



suggested by the transnational criteria is rather difficult to determine. Perhaps the best answer today is that some do, most do not.

In air transports there still is much nationalistic thinking shown through protection by legislators and bargaining by unions; however, consumers of today are really global in their attitudes. Consumers are renting cars from Hertz because it offers convenient service, reliability and value for money - not primarily because the company originates from a certain country. Even more clearly, in the manufactured goods sector consumers are buying, for instance, Nokia mobile phones because they offer versatile features, good quality and have aesthetically appealing design - not because they are manufactured mostly in Finland.

Management in any industry resist the loss of control. It is true that in airline business, just as in many other service businesses, the control of, say, quality aspects of the product is essential. However, airlines have a long time ago given up much of the control in one of the key functions as the sales function is outsourced to a high degree in most airlines. It is true that computerised reservation systems are used by airlines to control the sales and airlines actively try to have an impact on the sales managed by travel agents.

#### **The role of governments and unions**

International air traffic has been strongly affected by bilateral agreements between governments. As suggested by many observers, the process towards more liberal bilaterals, extensive multilateral arrangements, and open-skies agreements is still far from completed. It has been suggested that bilateral agreements have been a barrier to organic international growth for many airlines, and they could be considered tools of protectionism by nation states. The bilateral agreements have been an important variable when foreign ownership of airlines has been discussed; the system has historically built on the assumption that an airline based in and operating mainly from one country is also owned by parties of that country. Hence, if a British firm owned a US based airline wishing to operate on the Atlantic market between the US and the UK, the interpretation of the spirit of the bilateral agreement would be complicated. In fact the US government has limited the share of ownership by foreign parties in US airlines to 25 per cent.

A complication in the open-skies agreements is the issue of who are the parties to the agreements in the case of Europe. Namely, the European Commission sees that it should be the signing partner in the US-Europe open-skies deal. However, many of the member countries of the European Union would definitely like to have agreements between the nation states instead of between the Union and the USA.

In general terms, authorities have eased their regulation of the airline industry since the late 1970's, but they still play an important role. The liberalisation, or deregulation, of the industry has aimed at bringing competition to the market place, compelling airlines to better efficiency, and bringing benefits to consumers in the form of better offering of services at a lower price. The same rationale is seen in many other industries. There, eventual consolidation of the industry has often followed, mostly through mergers and acquisitions. In the airline industry, however,

authorities have been very strict about allowing particularly transnational mergers or acquisitions, something that puts airline management in a rather perplexing position. It seems that governments are very careful and protective of their national airlines - no matter if the government has an equity stake in an airline or not. To set this against a broader picture, one could ask why airlines should be treated by authorities with such a nationalistic ethos when the consumers, the flying passengers, no longer put much emphasis on the nationality of a carrier.

The well-known argument from the authorities - and a very much understandable and valid one - is that the consolidation of the airline industry would spell dangers particularly to the consumers: division of markets between few very large carriers, less competition, less choice, higher fares and poorer service. In other words exactly those problems that were tackled through the deregulation process started in the US in the late 1970s. While the argumentation by the authorities makes sense, it could lead to a re-regulated airline industry, where the competitive pressure would not drive airlines to rationalised operations and efficiency. The issue is about finding the fine balance between allowing airlines to rationalise operations through industry restructuring and, on the other hand, ensuring that there is sufficient competition between the large airline groups in most markets. Looking back at the history of industry deregulation it appears inevitable that there will always be certain markets where competition does not work and bring the benefits to the consumer.

It has been sometimes expressed by national authorities that the reason for being strict about allowing transnational mergers or acquisitions in the airline industry is the issue of national security. That may well be justified in the less and less common case of government-owned carriers, but in the case of at least partially privatised, let alone fully private airlines, the argument becomes somewhat old-fashioned. As noted by some observers, when even defence-related manufacturing industries are allowed to consolidate internationally, it seems strange to be so careful about air transports. After all, a clear distinction should be made between public services and business - military air lift capacity and commercial airlines should not be confused. A perspective of a private - and often foreign - share owner of an airline may be that he or she could not care less how some nation state organises her military air lift capacity. Moreover, in case air transport capacity needs arise for military purposes, that capacity is very likely available from the market, at market prices.

Another interest party to the issue of international airline industry consolidation is the labour unions. Interestingly it is the pilot unions that are working on transnational labour movement to protect the interest of their members. It appears that unions have opposed mergers and acquisitions - and appear to oppose large-scale alliances, too - because the M&A's and alliances might lead to more efficient organisation and thus lower demand for personnel. However, as suggested earlier by industry observers, it appears that in the light of the forecasted growth of demand for air transport it is an unwarranted fear that jobs would be lost in the industry as a whole. Perhaps it would be more correct to speak of only more slowly increasing need for personnel.

Another reason for union opposition may be the feared pressure on remuneration, which in the airline industry is very good across the board, compared to any other

industry. The remuneration pressure would partly be due to better exposure of performance and efficiency; this would very likely lead to unwanted changes in the organisation of inefficient carriers. However, it would be in the interest of the industry as a whole and the consumer in particular to have changes driven through in inefficient carriers.

## **DRIVERS OF INTERNATIONAL ALLIANCES**

In general terms earlier research has categorised the reasons for alliances, for example, as:

- risk sharing
- scale economies
- access to markets
- access to technology
- market convergence.

As to airline alliances, it has been suggested (see e.g. Alamdari and Morrell 1997) that there are two main drivers: first, search for more market power, and secondly, search for lower operating costs. These broad categories cover the two basic reasons for airlines' alliance arrangements, but it appears that there is room to elaborate further. More of an industry-level research (see Antoniou 1998) has suggested that the formation of mega-carriers - either through mergers or alliances - would appear to be a solution to the empty-core problem of the airline industry, pre-empting complete deregulation.

Studying the airline industry alliances of the past suggests that the role of authority control is an area which deserves to be brought up as a reason for alliances. The following factors – suggested in earlier research - can be seen as drivers of alliances in the industry:

- mergers and acquisitions in general have been tightly controlled in the airline industry,
- foreign ownership in airlines has been restricted by governments,
- bilateral agreements between countries make foreign ownership of airlines problematic,
- bilateral agreements have been a way of protecting markets.

As to restrictions on foreign ownership in airlines, it appears to be the control that worries authorities. The control by a foreign investor in an airline has been restricted by other means than ownership limitations, too, such as the number of members to be appointed in the board of the airline.

Considering their need for reaching the assumed economies of scale, scope or density, airlines have been left with very few options other than slow organic growth or alliances. In pursuing alliances airlines have due to government control had limited options, leading mostly to code-sharing arrangements.

### **Objectives of alliances**

Earlier research on strategic alliances - typically dealing with manufacturing industries - has pointed to two primary categories of objectives in alliance arrangements: product objectives and knowledge objectives. In the area of product objectives there appears to have been two primary goals: either the enhancement of product offering or the reduction of production costs. As to knowledge objectives, the goal has typically been to learn some specific new technology or process from a partner; it appears that the goals as to knowledge transfer have often been rather specified and particular.

### **Regulation as a driver for alliances**

This study examined the alliance history of the major airlines of the world using several sources of information such as general news services, industry press, and airlines' own publications. In order to illustrate the role of government regulation in the alliance development very brief summaries from a few key airlines are presented; the summaries are limited to international alliance activities from 1988 to 1998. The summaries have quotations from only one type of information source - airline annual reports to enhance the comparability of company views; namely the annual report is a key media to deliver messages to the investors, authorities and the public, and the messages need to be informative and truthful. Of course a lot is left unsaid in annual reports - for instance comments concerning some particular competitors - but that is likely to apply to any contemporary published material.

SAS started in the 1980's with a strategy of building alliances with airlines that were either smaller or of the same size as SAS itself. In the 1990's, under new leadership, the alliance strategy was refocused on partnering with large airlines. Also, SAS experience had taught that equity-based arrangements are very difficult to manage, and therefore further alliances would be pursued without ownership. Moreover, the emphasis in own operations was pulled back from global reach to concentrate on being a dominant player in the markets of the home region. It appears that the Star Alliance is seen to produce significant benefits in the short and medium-term in the area of marketing, and in the longer term additional benefits are expected from operational cost savings in maintenance, sourcing, handling, and so on. The role of regulation is seldom brought up by SAS management; however, the CEO Carlzon wrote in the 1992 annual report:

*In the future companies which obstinately uphold national interests and allow them to stand in the way of essential restructuring will have chosen the route towards elimination.*

In its 1989 annual report KLM emphasised the liberalisation of the European aviation as a motive to strive for co-operative links with other carriers. These links were seen to provide additional opportunities in both passenger and cargo markets to safeguard KLM's market position. The criteria for the co-operative links comprised e.g. securing or expanding the position of Schiphol (Amsterdam) airport as the gateway to Europe. Overall KLM's approach to alliances appears to represent a rather common way of seeing alliances. First of all, air traffic politics and the regulation by government authorities are both a major motivator and a limitation to the pursuit of alliances.

Secondly, it appears that the relative significance of market presence and more efficient resource utilisation varies by the economic turns: in good times market expansion appears as a key driver, but in harder times the need to reduce costs is emphasised.

It appears that *Lufthansa* management was not very keen on tying partnership knots with other airlines until the recession of the early 1990's really hit the company. The sentiment in the company in the late 1980's and early 1990's was that bilateral air traffic agreements were not providing fair playing field for the world's airlines. The significance of regulation as a motivator for alliances by *Lufthansa* is apparent; on the other hand, regulation is seen as a hindrance to alliance building. Overall *Lufthansa*'s participation in alliances appears to be justified through a combination of market presence and resource utilisation factors. It would appear that *Lufthansa* has seen more value than other airlines in the cost reduction possibilities that alliances may offer.

*American Airlines* has built its international operations quite slowly, operating first and foremost within the USA. The strong areas for *American* outside the USA have traditionally been the Caribbean and Central and South America. Even in 1990 *American* operated only to eight countries in Europe, but in the 1990's the international expansion has been significant. The international growth has been primarily internal, although *American* has acquired international routes from other airlines such as *Eastern* and *TWA*. *American* has been perhaps the most active airline to participate in the international air politics debate and has demanded more opportunities to operate internationally on a competitive basis, as illustrated by the following quotes from the 1990 annual report:

*Unfortunately U.S. airlines seeking to spread their wings in international marketplace face some daunting barriers, most of which – since they are rooted in the protectionist policies of foreign governments – can be overcome only by an active partnership between industry and government.... Since they [bilateral agreements] assign a higher priority to the welfare of national airlines than to the health of national economies, they are entirely inconsistent with today's economic realities.*

The full realisation of the alliance with *British Airways* has been delayed for years. In 1997 *American* CEO Crandall wrote in the annual report:

*Because the airline industry is increasingly global, remaining competitive requires us to serve the largest possible number of origin-destination markets world-wide... The American-British Airways alliance is the centrepiece of a pattern of alliances we have been building as we adjust to the changing nature of international competition.*

The 1998 *American* annual report wrote:

*By granting antitrust immunity to alliances between U.S. and foreign carriers, the U.S. has made international alliances a virtual necessity. American has reacted to the changing environment by setting out to create the industry's premier set of alliances.*

*Delta Air Lines* purchased nearly all of the collapsed *Pan Am*'s transatlantic routes, shifting its focus from being a predominantly U.S. domestic carrier to that of being a

global airline. In the early 1990's Delta stated that a part of its international strategy was to use code-sharing with other quality airlines to support Delta's international service. The reasoning was that this enabled Delta to remain in markets that would be unprofitable to fly alone, and to offer service in new markets without major capital expenditures. In the annual report 1994 it was reported:

*Delta will continue to advocate a more open, market oriented operating environment...Delta's goal is to serve its customers while increasing efficiency and expanding market presence by developing a network of mutually beneficial code-sharing alliances.*

By 1995 the international code-sharing arrangements had been made with Aeromexico, All Nippon Airways, Austrian Airlines, Korean Air, Sabena, Singapore Airlines, Swissair and Virgin Atlantic Airways. In 1996 there were 13 code-sharing partners; with three of them Delta received approval of antitrust immunity from the U.S. Department of Transportation to pursue a global marketing alliance. This marketing alliance called Atlantic Excellence between Delta, Austrian Airlines, Sabena and Swissair included - in addition to code-sharing - pricing, scheduling and other operational co-ordination; joint sales and marketing were still seen as "opportunities". The 1996 annual report reported:

*...The alliance agreements establish a legal framework...to allow the four carriers to form a seamless transatlantic air transport system while retaining their unique corporate and national identities...*

In 1997 Delta announced code-sharing arrangements with Air France, China Southern and Transbrasil. Considering Asian operations the 1997 annual report notes:

*Delta continues to pursue additional authorities to serve Japan, but is impeded by the highly restrictive aviation agreement between the U.S. and Japan. Delta's limited Japan services will be supplemented by additional service to Asia through code-sharing arrangements with China Southern and Korean Air.*

In 1998 Delta and United Airlines agreed on a broad marketing relationship; however, due to opposition from the pilots' union Delta was not able to proceed with a code-sharing arrangement with United, but had to continue the co-operation through reciprocal frequent flyer program only. In the annual report for 1998 Delta underlined the role of strategic alliances:

*Delta will proceed aggressively with world-wide alliance discussions in the future, not just because alliances are desirable from a business standpoint - although they are - but also because we must. Airline alliances are revolutionising the nature of world-wide competition, and Delta intends to be a leader as these changes occur.*

In about seven years Delta has grown from a domestic carrier to a significant global player, much thanks to alliance arrangements particularly in Europe. For example, Delta has been since 1997 the largest operator on the North Atlantic market, the largest and most competitive international market in the world. In Delta's history of international alliances the evasion of regulation and the market power as drivers appear to stand out, and the resource utilisation improvement seems to be primarily Delta's internal effort.

### **Model for international airline alliance dynamics**

Based on the study within the airline industry a model (Figure 1) is suggested on the dynamics of international alliances, depicting factors that have been the drivers of the alliance efforts. The model is set in a framework where the relevant recent changes in the airline industry are shown, as well as the consequent basic strategic choices and the alternative strategies for airlines; the model builds on a strategy framework presented earlier (Seristö 1993).

*(Insert Figure 1 about here)*

There are numerous factors, many of which have been touched upon in this article, that effectively limit the basic strategy choices of airlines into three: growth strategy, focus strategy and lowest cost strategy. Growth can be sought either internally (organic growth) or externally. As internal growth is often slow, it may be preferable under the present circumstances for many airlines to seek growth externally; then the options are mergers and acquisitions or alliances. As there are many limitations to airline mergers and acquisitions, alliances provide often a less complicated route for growth. Alliances provide more flexibility than outright mergers and acquisition, and they are likely to carry less risks than M&A's.

Even if an airline would choose focus as its basic strategy, there are pressures in the competitive environment suggesting the utilisation of alliances. Whether the airline bases its strategy on different customer groups (e.g. business travellers) or on certain geographic area (e.g. traffic between Europe and South America), it is nevertheless likely to benefit from some sort of partnership with suitable airlines. The simple rationale is that no matter what the niche or specific geographic market is, an airline is likely to benefit from a larger catchment area and better connections.

As to the airlines choosing the lowest cost strategy, alliances may be of lesser importance, at least in the light of today's experiences from the nature of operations by low-cost carriers. In Europe the low-cost airlines, in practice charter carriers, typically cater for tourist traffic in and out of holiday destinations, and in this type of traffic connecting flights provide only limited value added. Elsewhere in the world, primarily in the U.S.A., low-cost carriers serve the business traveller segment, too, but so far a major part of the business has been on domestic point-to-point markets where the value added provided by good connections is not necessarily essential. Here it is necessary to make a distinction between low-cost carriers such as Southwest Airlines and the feeder carriers, such as American Eagle. However, the fact that today alliances of low-cost carriers are rare should not be interpreted so that there is no potential in building an international alliance of low-cost carriers for the ever-more important leisure travel segment; in fact that might provide interesting opportunities in the ever more global tourist market of the future.

As to the drivers of international alliances, it appears that, first, the changes in the industry have made it essential for most carriers to seek growth and to secure presence in a larger market; second, the many types of regulation in the industry make alliances the only feasible way to grow and seek presence in a larger market; and third, there is a pressure to utilise resources better, i.e. to reduce the operating costs.

Getting around various forms of regulation in the airline industry is a major motivator for alliances. For one thing, the fact that governments still are notable owners in many internationally operating airlines makes acquisitions of and mergers with airlines somewhat problematic in general - namely, national flag carriers are still considered in many countries part of national property and country image, and therefore foreign ownership is not seen favourably. Secondly, governments have often set specific limitations on the share of foreign ownership in the airlines of their nationality. Thirdly, antitrust legislation makes mergers and acquisitions problematic in many countries because these often would lead to a dominant if not monopoly position of the united firm at least in some markets; the background for this is that for historic regulatory reasons there are very many markets where a duopoly exists. Finally, the fact that bilateral agreements between countries still form much of the basis for international air transportation causes some problems.

Securing market presence can be seen either as an offensive objective of alliances, typical for large airlines, or as a defensive objective, typical for medium-sized and small airlines. Larger airlines seek market power and consequent enhanced value for customer by pursuing larger network coverage, higher frequencies, more extensive loyalty programs and dominance of so-called hub airports through alliance arrangements. Medium-sized and small carriers appear to seek more market coverage rather than outright market power in order to respond to the challenge by expanding larger airlines; smaller carriers seem to consider participation in alliances essential in trying to avoid shrinking into mere regional operators - which, of course, might be the destiny of small carriers even with alliance arrangements. In the market presence objective of airline alliances it is necessary to distinguish the global level and the specific market level, which may require arrangements of conflicting interests. For example, for many reasons it is valuable for SAS to co-ordinate closely its operations on a global level with its Star Alliance partners, but in the specific markets of the Nordic countries SAS may need to deviate from the ideal Star Alliance strategy because it needs to respond decisively to the challenges by Finnair, a key rival in the home market of SAS.

The third motivator for alliances is the need to utilise resources better. This can be pursued either through higher productivity or simply lower costs. Higher productivity is sought, for example, through sharing aircraft and air crew capacity, using partner's ground handling and airport passenger services at foreign stations instead of providing them by the airline itself, and making better use of possible excess aircraft maintenance capacity by servicing partner airlines' aircraft. Capacity sharing arrangements can often be complemented by specialisation; for example, one partner can specialise in the maintenance of aircraft engines from a certain manufacturer and another partner in engines from another manufacturer. As to direct cost savings, for example joint sourcing of fuel, catering (food), aircraft, spare parts, or information and marketing services may produce significantly lower costs than sourcing alone by each partner.

As to the relative role of the three alliance motivators it appears that it is the pursuit of stronger market presence that clearly has been more apparent and dominant, the need



for better resource utilisation being secondary and also more of a longer-term nature. Concerning the role of regulation and the need to circumvent it, the assessment is somewhat difficult. It seems very often to be a key factor in alliance building, part of the environment for nearly all airline cooperation.

It appears that different drivers have a different nature, or perhaps justification, in different kind of airlines. In this respect airlines can be grouped roughly into large and small firms, and the relevant dimensions for the nature of drivers can be determined as tactical-vs.-strategic and defensive-vs.-offensive. Figure 2 illustrates the positioning of the drivers along these dimensions for large airlines, and Figure 3 for small airlines.

*(Insert Figure 2 about here)*

*(Insert Figure 3 about here)*

It was found out in the study that the role of learning from partners in airline alliances is evidently quite insignificant. Very much differently from many manufacturing industries, where the ability to learn from a more experienced or otherwise better partner is often given as a reason for building alliances, in this study the factor hardly ever came up. Even if it is understandable that airlines are not very eager to publicly shout about their needs to learn from other airlines, thereby indicating their own possible deficiencies, it still appears that airlines generally speaking do not make sufficient use of the opportunity to learn better practices.

Turning competitor airlines partners rather than rivals would appear to be a very valid motivator in today's airline business. This, however, hardly ever came up specifically along the study. Certainly it is true that firms are not keen to pinpoint their archrivals in an industry of such turmoil - where today's rival can be tomorrow's partner and vice versa - but nevertheless it was somewhat unexpected that something which is here called competitor taming was never really suggested by the airlines. Earlier research, mainly concerning manufacturing industries, has suggested that making friends out of foes would be a motivation for many alliances. What is called competitor taming here is very close to what Doz and Hamel (1998) have termed "co-optation". Again, just like with regulation evasion, the airlines' rush for market presence and for resource utilisation perhaps just overshadows the competitor taming as a motivator for alliances, but presumably it is a hidden factor in many alliance cases.

One outcome of the study is the evidence of the essential role that market presence plays in airlines' strategic planning for survival and prosperity - having global reach appears to be a must in most airlines' strategic plan. Also, it appears that resource utilisation is a factor often acknowledged but quite slowly actively pursued. One explanation for this slow action is, of course, the rigidity that airline management face due to both very strong labour unions and regulation by authorities. However, overall it appears that the firms are rushing so hard to secure positions as to their market reach that they are paying perhaps too little attention to the longer term factor of learning from alliances. Maybe the history of airlines as national icons, at least in Europe, have created corporate cultures that are not the best environments for absorbing new

practices. It would seem that the crisis of the industry in the early 1990's has brought some more flexibility in many airlines, but a comparison to other industries would indicate that there is still quite a way to go, but a way with great potential.

### **Managerial challenges**

It appears that alliance building is such a part of evolution in the airline industry that most airlines need to participate in - the opportunity cost of not participating might prove too high. Management in airlines face considerable challenges in making the alliances work: there is the pressure from authorities, demands by unions, perhaps mixed ownership by government and private parties, and the normal challenges of different cultures in different countries and firms, differing organisational arrangements in airlines, and strong personalities as airline executives.

Managing the relationship with the governments and even local authorities would appear to be a major task for airline management of the future. In addition to the national interests - country image, employment and balance of payment issues - the increasing role of ecological aspects (noise, pollution) will add to the importance of managing all sort of regulation.

Outside regulation issues, it seems that the area where airline management face hardest challenges and where there appears to be much potential for improvement is that of learning. Earlier research (Inkpen 1998, 225) has emphasised the role of trust between the partners as a contributor to successful learning. It is the very notion of trust that makes airline alliances different from those in many other industries: so far alliances in the airline industry have been either very short lived or limited in scope, or both, and therefore the trust has not been developed between the partners.

### **SUMMARY AND CONCLUSIONS**

Changes in the industry have made it essential for most airlines to seek growth and to secure presence in a larger market. There is again the pressure to reduce operational costs in airlines through better utilisation of resources. Finally, the many types of regulation in the industry make alliances the only feasible way to grow and seek presence in a larger market.

Airlines appear rather frustrated by the fact that the natural evolution towards transnational companies in this industry is effectively blocked by authorities. This frustration is echoed in the comment by Paul Moore, spokesman for Virgin Atlantic, concerning U.S. limitations for foreign airlines on acquiring or setting up a U.S. subsidiary:

*It's blatant protectionism. Alliances are an artificial solution to an artificial problem. There is no reason why the rules should not be different now.*  
(*Airline Business*, October 1998, p. 76)

As to governments' role in regulating the formation of truly transnational airlines, it appears to be a question of finding the right balance between enough freedom to allow efficiency in the global airline industry to develop, but enough regulation to make sure that there is competition between the alliance groups at least in most markets.

Market presence appears to play an essential role in airlines' strategic planning for survival and prosperity - having global reach appears to be a must in most airlines' strategic plan. Therefore the primary motivation for international alliances so far has been the need to secure an extensive catchment area or a large onward connection network.

It seems that resource utilisation is a factor that is very often acknowledged in international airline alliance arrangements. However, airlines have in fact been rather slow in pursuing higher productivity or outright lower costs through concerted efforts with partners; there seems to be rigidity in airlines in operationalising the changes and therefore the resource utilisation has so far not been as significant a motivator as market presence.

Overall it appears that the pursuit of stronger market presence has been more apparent and dominant, the need for better resource utilisation being clearly secondary and also more of a longer-term nature. The role of regulation and the need to circumvent it is rather difficult to assess. It seems very often to be a factor in alliance building, but very rarely is it expressed as the primary reason. However, the demands from the airlines to allow more freedom to rationalise and restructure the industry may get more outspoken in the future.

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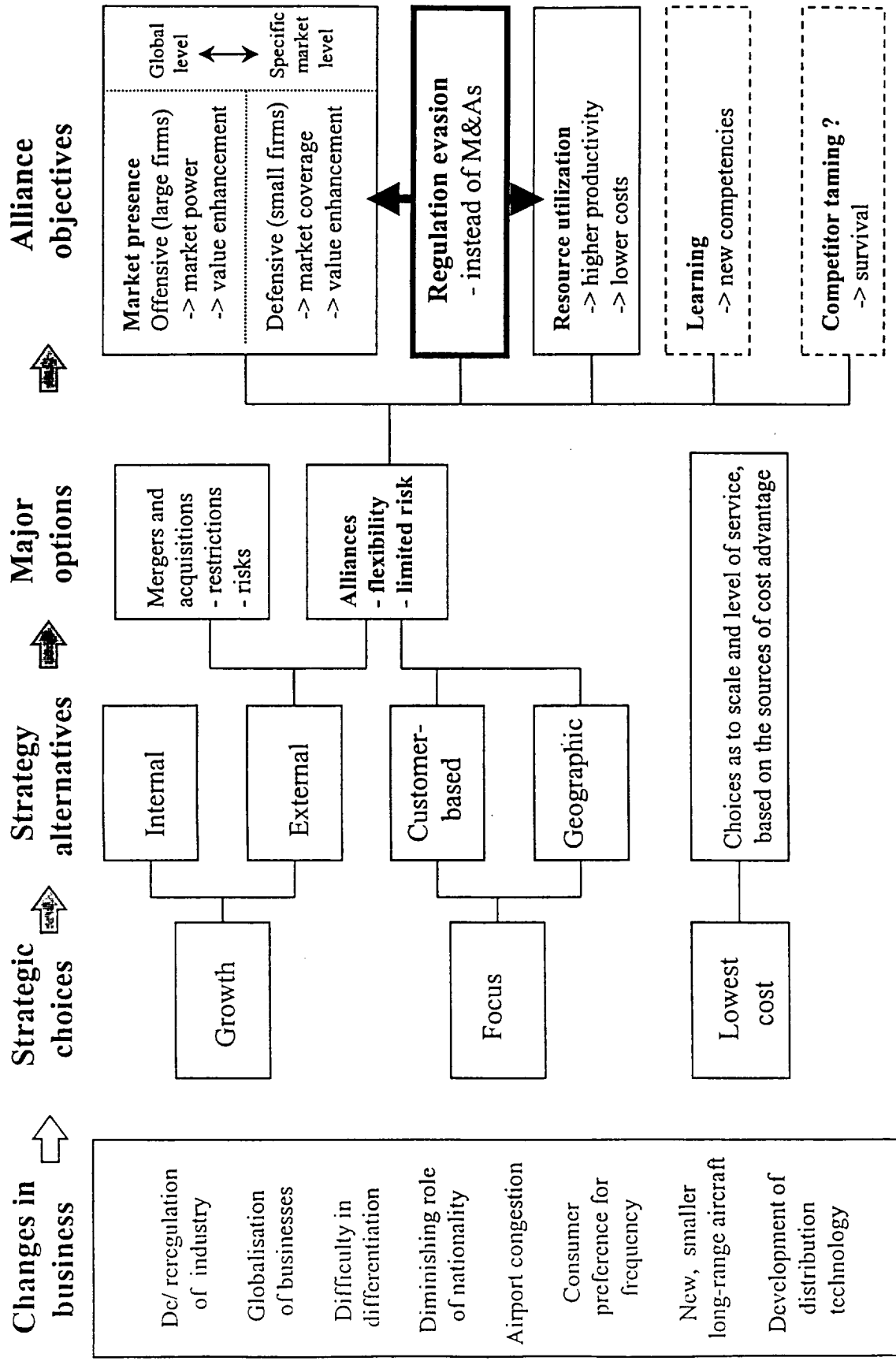
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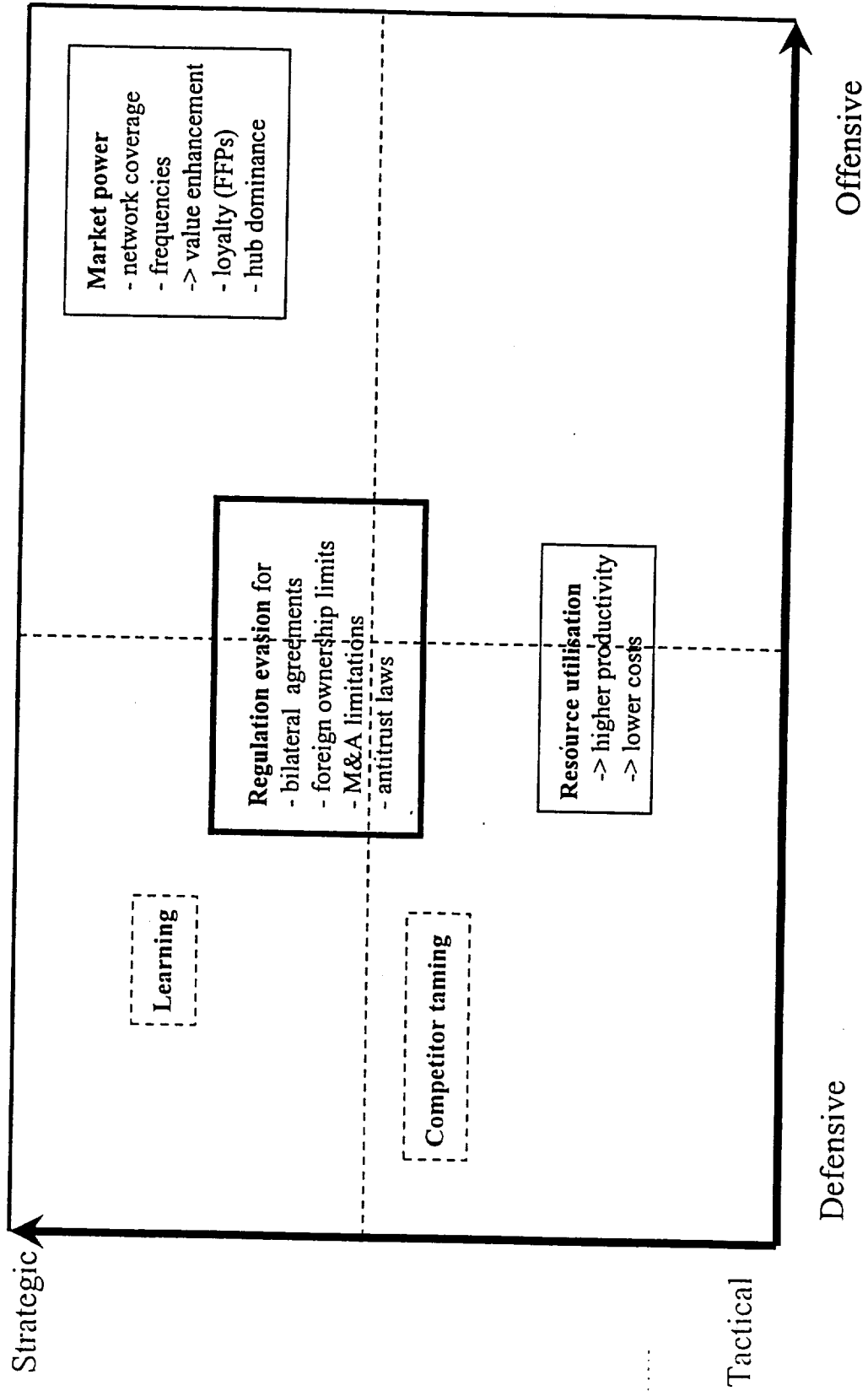
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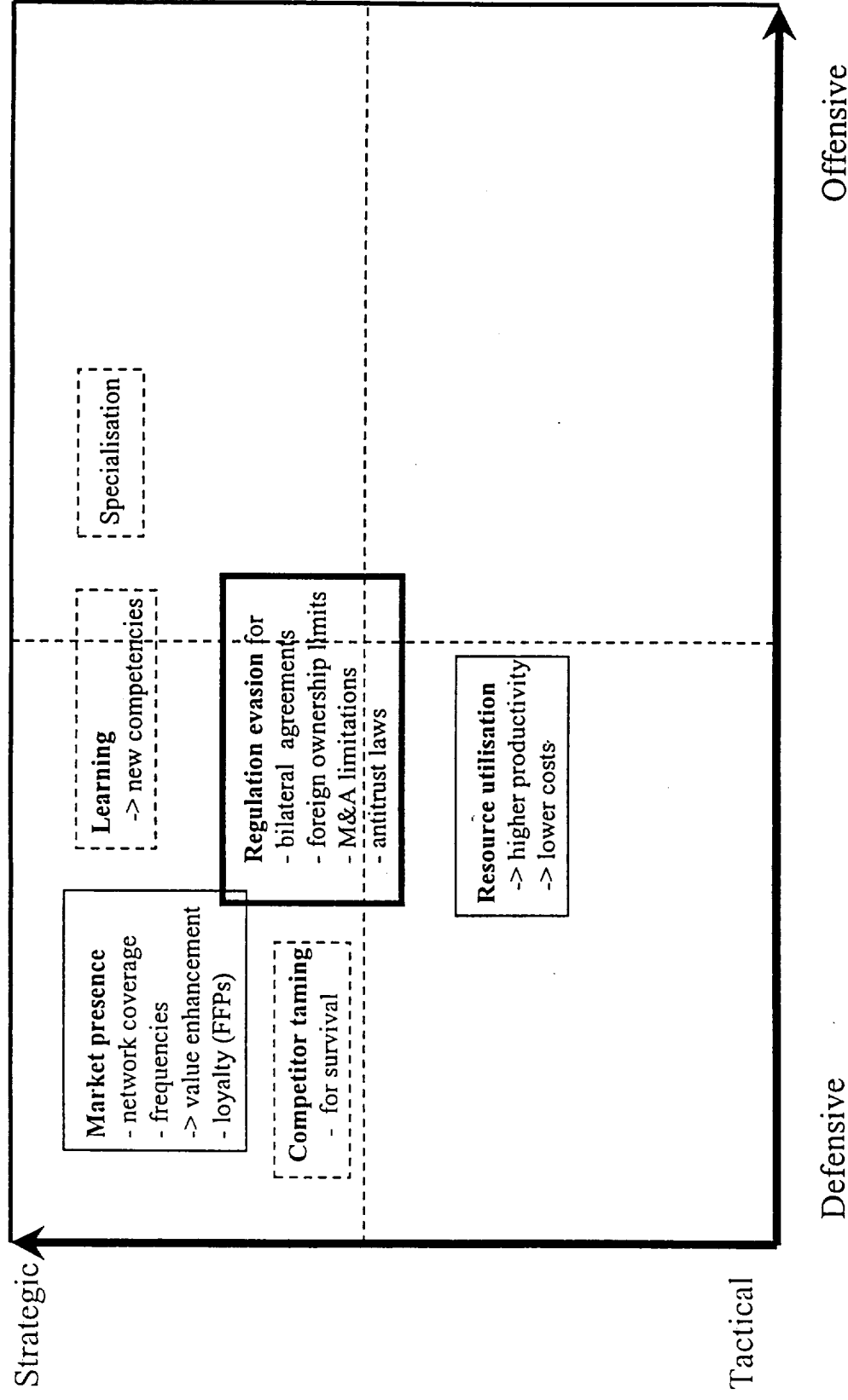


**Figure 1 Regulation as an alliance objective in the strategy framework**



**Figure 2 Drivers of international airline alliances - large carriers**





**Figure 3 Drivers of international airline alliances - small carriers**

Air Transport Policy in Japan:  
Policy Change and Market Competition

**Hiroataka YAMAUCHI,**  
*Professor, Faculty of Commerce, Hitotsubashi University.*  
Tokyo, Japan

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## 1 Introduction

Japanese air transport market developed in a strictly regulated environment. The Civil Aeronautics Law, which governs the industry, requires that firms should obtain government licenses to get into the market. Airlines also need government approval for their fares, and even for their annual business plans.

But a policy stream toward liberalization of air transport since the 1980s has brought to fruition of substantial deregulation in this market. Now the Ministry of Transport (MoT) is going to submit a bill to the Diet, which revises operating licensing system, fare approval system and other regulatory provisions. Moreover, since the MoT relaxed its operating standard of administrative process, we can say that now the airline industry is under competition. As widely reported, newly established carriers entered into markets and their impacts on market competition were strong although shares of new companies are quite small.

As for international air transport, liberalization has been also in advance. The Memorandum of Understanding concluded on March 14 1998 with the U.S. government was an outcome of negotiation to equalize the right and interests between two countries, but its essential factors are thought to be giving airlines of both countries with freedom to conduct in the market place. And strategic alliances among world airlines will make it more severe to compete in international markets.

Facing with the new stage of competition among air carriers, we have to move on a new air transport policy, which should pursue efficiency and fairness in this market. Needless to say, efficient air transport system is the infrastructure of sound economic development and globalization of economy. ~~In this sense, it is thought to be very important that each of three governments, Japan, Korea and China, has responsibility to facilitate efficient air transport market in cooperation with each other.~~

## 2 DEREGULATION OF THE DOMESTIC MARKET

### 2.1 Abolition of Supply-Demand Balance Clause

In Japan, we are now facing a powerful policy trend reconsidering the role of the government in economic policy, and there are emerging consensus that deregulation is the only way to revitalize the economy as a whole, to recover international competitiveness

and to benefit consumers. The transport field is not an exception.

On December 5 1996, the MoT announced that it would abolish supply-demand balance clauses in every transport business law including the Civil Aeronautics Law in a couple of years. A supply-demand balance clause provides that a new entry or increase of supply by existing carriers could be approved if and only if the MoT make a judgement that the balance of supply and demand in the market would be disturbed. This is a typical quantitative control of supply and the clause might effectively block new entry.

The ~~clause~~<sup>clause</sup> has also given the MoT with wide range of administrative discretion, because, according to the clause, it is not the company managers but the government officials that judge whether there is excess demand or not. The abolition of the clause means that that there could emerge much room for effective competition carriers than in present situation, since managers become able to make decision on their own judgement and to take actions timely.

## 2.2 Industrial Policy in Air Transport: an Old Regime

As noted above, Japanese airlines were fostered in strictly regulated environment. The governmental intervention in this industry was conducted not only through statutory actions but also through purely administrative process such as a cabinet meeting resolution and a notice from the Minister of Transport. Especially, the Cabinet Meeting Resolution in 1970 and the Notice from the Minister of Transport in 1972 played a role to fix the market structure in the air transport and some times called "Aviation Constitution". The Civil Aviation Law and administrative guidance did not allow airlines from competing rigorously.

This "old regime" was intended to secure and nurture the capacity of all members of the airline companies by establishing segmented business fields for each firm. The segmentation of market was also a common feature of Japanese industrial policy in 1950s, 60s and first of 70s. In air transport case, routes licensing regulation could make the segmentation concrete and trunk routes markets offered a base for operational stability and became source for cross-subsidization.

The old regime survived until mid-80s, with all three firms growing steadily within an arranged business base. The air transport market as a whole grew rapidly with a help of Japanese high economic expansion, and the route network was widened. The role of

governmental intervention in the form of protection of infant industry can be said to have functioned adequately up to this stage. But the most serious problem of such a cartel-oriented government policy was that the high cost nature of airlines was bought about by protection from competition and that it remained even after the situation was changed.

### **2.3 Policy Change in the Last Decade**

The old air transport regime collapsed in mid-80s. The trigger was the conclusion of the Japan-U.S. Aviation Treaty Interim Agreement of 1985 and the signing of its Memorandum of Understanding. The strategy of the Japanese government in the 1970s was to limit international schedule carrier to Japan Airlines (JAL), but, the Interim Agreement admitted the new entry of Nippon Cargo Airways (NCA), moreover it allowed other new carriers of both Japan and the U.S. to start scheduled passenger services. Naturally, to make this possible, it was necessary for the government to end JAL's monopoly over scheduled international service. Around this time, calls for the liberalization of the Japanese domestic air industry was also strengthened, and the Council for Transport Policy (an official advisory committee to the Minister) announced its opinion that the Old Regime formed in the first half of 1970s should be abolished, and that more pro-competitive air transport policy should be pursued. The content of its detailed advice were as follows:

- (1) International routes would be served by multiple carriers;
- (2) Competition on domestic routes would be promoted by new entry into particular city pair markets; and
- (3) Japan Airlines would be completely privatized.

The government insisted that domestic aviation has moved onto a more competitive situation, because of the new aviation policy adopted in 1986. However, the system has met critics that the government's regulation of fare approval and entry licensing has basically remained unchanged, so even though several carriers compete over the same routes, these routes are subject to an entirely uniform fare structure.

In response to such critics, the government adopted a policy that makes it easier to offer discounted fares in 1995 and a zone-fare system in 1996. This zone fare system adopted is similar to that adopted by European Communities (now European Union) before the third package of common air transport policy was implemented in 1993. The system

involves establishing a fixed price range and allowing carriers to set their air fares within that range at their own discretion. Needless to say, this allows carriers to respond to a particular demand period with a flexible fare structure. Carriers can introduce and set all types of discount fares, including advanced purchase fares, to meet the demand of different periods.

The upper limit of the permitted fare zone is initially calculated based on the airlines' cost level. The lower end of the range is set at 25% less than the upper limits for normal fare. The carrier can set discount fares at a maximum of 50% below the lower limit. Logically, the deepest discount fare could be set at 62.5% off compared with the upper limit fare.

### 3 Competition in the Domestic Market

#### 3.1 Demand Structure

The five-year growth rates in the number of air passengers are 9.7% (1975–80), 1.6% (1980–85), 8.3% (1985–90), and 3.7% (1990–95). Demand is periodically hampered by the capacity of Haneda Airport, which expanded in July 1988 by the New A runway and again, in 1998, the New C. Given Japan's geographical size, the air transport market in Japan is not small. The revenue passenger kilometers (RPK) in the domestic market total about 65 billions, one-tenth the U.S. figure, and 78 million passengers fly domestic routes, which is one-sixth the size of the U.S. market (1995 data).

Using time-series data from 1974 to 1995, I estimate the aggregate demand function as follows:

$$\ln(RPK) = 10.157 - 0.741 \ln(RFARE) + 1.292 \ln(RGDP), \quad \text{adjusted } R^2 = 0.982,$$

(5.430)
(-3.665)
(12.782)

where  $RPK$  = revenue passenger kilometers,  $RFARE$  = real airfare (domestic yields per  $RPK$ , deflated by the CPI),  $RGDP$  = real GDP.<sup>1</sup>

Simple aggregate demand function analysis indicates that the long-term price elasticity of domestic air travel is about -0.74 and the long-term income elasticity is about +1.29. Compared with Ohta (1981), that suggested comparable figures of -0.83 and +1.66, my estimate shows an income elasticity decrease owing to the newer data set.

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<sup>1</sup> I estimated several other functional forms, including a dummy variable for fatal accidents, but the simplest

The most important feature of this demand is the concentration on Tokyo routes. As shown in Figure 1, Haneda Airport handles about 55% of total air passenger in Japan, although the number of routes originating or terminating there only account for 17.9% of all routes. This is because many dense markets are involved, and revealed in Figure 2. Annual traffic on the Tokyo - Sapporo route is 7.6 million passengers, which is the largest in the world, and for Tokyo - Fukuoka route the figure is 6.2 million, which also ranks high in the world. The only non-Tokyo route ranked in the top ten domestically is Osaka - Sapporo.<sup>2</sup> These demand features highlight the importance of operating rights at Haneda Airport, especially in view of the high-cost nature of Japanese air carriers.

### 3.2 Carriers

Eight scheduled airline companies operate in Japan. JAL, All Nippon Airways (ANA), and Japan Air System (JAS), these are the three earliest. Japan Asia Airlines (JAA) and Nippon Cargo Airways (NCA) offer only international service. Japan Trans-Ocean Airlines (JTA) and Japan Air Commuter (JAC) are solely domestic carriers, and Air Nippon (ANK) is mainly domestic but recently opened an international route between Fukuoka and Taipei. Note that JAA and JTA are subsidiary of JAL, NCA and ANK are of ANA, and JAC is of JAS.

In 1998, newly established two carriers entered into the domestic market, which are Skymark Airlines and Hokkaido International Airlines (Air DO). Skymark operates only in Tokyo - Fukuoka route and Air DO in Tokyo - Sapporo. These carriers very small and flights are very few, but since their fare strategy is very aggressive (very cheap), they succeeded in getting popularity.

The largest is JAL, and in 1995 it carried about 72.4 billion RPK in domestic and international markets. This is one-half or one-third the figure for U.S. mega-carriers. The second and third largest are ANA (about 43.8 billion RPK) and JAS (13.7 billion RPK). When the Japanese economy was booming, the airlines made big profits, but along with recession have come big deficits. The air transport market is becoming stable, but the airlines are restructuring.

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one fit the best.

<sup>2</sup> The top three U.S. markets are between New York and Los Angeles, Chicago and Washington, D.C., each with annual passengers of between 2.5 and 2.7 million.

As noted earlier, one regulatory objective has been cross-subsidization between trunk routes and local routes. The extent is unknown because profit and loss accounting by routes is not reported to the public, but it is said that two-thirds of JAS's routes post losses, and that is why it objects free entry and exit policy. It is claimed that unprofitable routes would be abandoned, and passengers without substitute transport modes would suffer. From an economist's point of view, however, the solution for that would be to maintain service by general government subsidy. The United States has the Essential Air Service Program, and the EU's third package of Common Air Transport Policy has similar program. The Japanese government is now seeking for a new direct subsidy system to be implemented at the next stage of air transport liberalization.<sup>3</sup>

### 3.3 Market Structure

Under the old regime, ANA had a major share in domestic market, but Figure 3 shows a decline from 57.4% to 47.2%. In a sense, this resulted from market liberalization, but it should be noted that none of ANA's competitors increased its share dramatically. Rather, each gained a few percentage points, while ANA's subsidiary, ANK, increased its share by 2.5 percentage points. ANA transferred unprofitable routes to ANK to make its financial position healthier. The government policy adopted in the mid-1980s has not led to radical change in market structure.

ANA has not lost share dramatically because of a strong sales network and brand loyalty in domestic the market, which were nurtured under the old regime. Furthermore, until very recently, fare competition was not allowed, and new entrants had no effective means to fight incumbents. In a sense, this also is a legacy of the old regulatory environment.

Another reason shares have not changed is airport limitations. As stated earlier, Haneda is the biggest profit center for carriers but does not have enough capacity. Landing slots have not increased much, although the expansion project is underway. In such a situation, incumbents have a competitive advantage over new entrants but not other incumbents.

Structure has changed in terms of city-pair markets with multiple carriers. Figure 4

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<sup>3</sup> In April 1998, the Council for Transport Policy submitted a report on further liberalization of the air transport market, in which it was proposed that a new subsidy program should be established.



shows changes in the percentage of passengers by market type: single, double, and triple trucking routes. After the policy change, passenger traffic on multiple routes increased steadily, reaching to about 72% in 1994. This means that the majority of passengers could choose their carrier. But, as stated above, carriers did not have flexibility in setting fares and even passengers with choice of two or more airlines did not enjoy the benefits of competition, as there were no difference in service or prices.

### **3.4 Airfare Trends**

The trend in average domestic airfares since the mid-1970s is shown in Figure 5. The average is calculated by dividing total revenue by total passenger kilometers for all carriers. Until recently, domestic airfares were tightly regulated, and the average remained relatively stable at least in nominal terms during the 1980s, after a hike in 1980 due to the second oil crisis in the previous year. Stability in nominal terms generally means a decline in real terms.

We can identify the downward trend in airfares since 1990 in nominal as well as real terms. In this period, fares were still regulated, but carriers could offer travel agents discount fares for inclusive tour programs, which might be used illegally for seat sales. So we cannot deny the possibility that the downward fare trend in 1990 reflects entry relaxation in the mid-1980s with a time lag. But it should be noted that the Japanese economy was in depression, and the fare decrease could be due to the weak economy. In any case, air passengers did not realize benefits from competition, and this led to demands to relax fare regulation.

The zone fare system was introduced in June 1, 1996, and in spring 1997, MOT reported on a comparison of the average fare with the previous year. As seen in Figure 6, the average fare declined by 2.3% in nominal terms. Since general consumer prices remained fairly stable during this period, this can be regarded as a real price decrease. The reduction is not trivial, considering that the annual rate of decline in U.S. domestic airfare since deregulation is 2.8% in real terms.<sup>4</sup> It is not clear that this price decline was mainly due to the new zone system. The average domestic fare had started to decrease since 1990, and the drop between 1994 and 1995 was 3.5% in both nominal and real terms.

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<sup>4</sup> According to Air Transport Association data, average U.S. airfare in 1977 was 13.4 cents per passenger mile, which declined to 8.07 cents in 1995 (calculated in constant dollars based on 1982).

Judging from aggregate data, domestic airfares in Japan have declined at a nontrivial rate, but consumers do not perceive much change. The main reason for their feeling seems to be that the absolute level of airfare in Japan is higher compared with that of other countries, especially the United State.

#### 4 REVOLVE OF INTERNATIONAL AIR TRANSPORT

The operation of international air transport is based on bilateral agreements, which reflect reciprocal rights and interests of each country. Owing to protection of rights and interests, the negotiated traffic level is likely to be lower. The country with less competitive and less efficient carriers may well try to protect its airlines and to limit the within which its carriers can compete safely.

A cartel initiated by the International Air Transport Association (IATA), stabilized international airfares and avoided substantial competition. Although IATA still exists and the Traffic Conferences of IATA are held regularly to set fares route by route, its ability to contain competition has been reduced. Its main role has shifted to cooperative functions, such as a debt and credit-clearing house for airlines. The degree of competition in international markets depends on the bilateral agreement, especially the capacity control clause.

The Japanese government was persistently taken a rather traditional stance on international aviation negotiations, a turning point in 1986 when the Council on Transport Policy submitted a report that suggested a new direction. The background to this report was the provisional agreement with the United States made the previous year, which allowed more Japanese and U.S. carriers entering the market between two countries. By this agreement, ANA and JAS became international carriers, and United, American and Delta obtained access to Japan.

Although this provisional agreement was not a liberal agreement giving carriers freedom in terms of capacity and price setting, it triggered changes in Japanese air transport policy. It was the starting point for relaxing entry conditions and expanding capacity expansion in international air transport markets.

The reason the Japan-U.S. provisional agreement is not more liberal is that the Japanese government believes that there is an inequality of rights and interests in the Japan-U.S. bilateral agreement, and that this inequality hampered fair competition in air

transport market between two countries. The Japanese government insists that the following inequality pertains. First, in the original agreement, the United States has unlimited fifth freedom rights beyond Japan, while Japan has only one point of that right beyond the United States. Second, the United States has more full right carriers than Japan. (Full right carriers can increase or decrease capacity without advanced notice.) Third, there is an imbalance in the capacity provisions in the North Pacific markets. Fourth, as a result, U.S. carriers can attain a greater share than Japanese carriers in that market.

Not all researchers agree with these assertions. It is pointed out that one cause of imbalances in capacity and market share is the failure of Japanese carriers to expand their capacity. It is true that there is an inequality in the beyond rights between two countries, but it is worthwhile noting that these rights are not so attractive to Japanese carriers because of Japan's geographical location.

Generally speaking, the complaints from foreign countries regarding Japanese international aviation policy focus on the difficulty in entering the Japanese market and in increasing their capacity. These complaints are partly caused by Japan's policy, largely stemmed from airport congestion problems.<sup>5</sup>

In March of 1998, Japan and the US agreed a new memorandum of understanding. In the negotiation process, while the US government strongly insisted that Japan should accept the liberal agreement, since the Japanese government refused it persistently, the MoU was not said to be a liberal agreement. The official reason why Japan opposed the liberal agreement was that there remained the inequality of rights and interests in the bilateral mentioned above.

However, the essence of the MoU was to introduce a greater competitive environment into the North Pacific market. The new agreement allows for full right carriers to choose any city pair market between two countries if there is no landing slot problem, to exercise beyond rights more freely than present<sup>6</sup>, and to take use of code sharing even between same country's carriers. Moreover, the agreement equalizes the number of full right carriers for two countries, which could meet Japan's complaint about inequality in the original

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<sup>5</sup> As for the detail discussion on US-Japan bilateral agreement, see Yamauchi and Ito (1996).

<sup>6</sup> While there remained preconditions on using beyond rights for both countries, these conditions are not restrictive.

bilateral agreement while for the non-full right carrier, flight increase is allowed. The new agreement was concluded with substantial compromise of two countries, but it is sure that competition among carriers will increase and increased competition would benefit consumers as well as air carriers themselves.

## 5 CONCLUSION

In this paper, we have examined change in Japan's air transport policy. Air transport industry is quickly metamorphosing, so the policy should keep pace with its object. It should be noticed that competition makes airline more efficient and more competitive, and that sound air transport system brings huge benefits to consumers and global economy consequently. So the ultimate purpose of the policy is nothing but enhancing the competition in this field.

But it is true that there are several problems to be solved in promoting competition in the air transport market.

First, in order to make the competition fair and workable, we have to make sure of the equal footing for the market competition. For example, since the congestion in airport would be main obstacle to new entry and strategic decision making, we have to invent transparent and efficient procedure to allocating landing slots. In the international context, the government aids to its flag carrier are the most controversial problem. In the EU case, they put the judgement on legitimacy of government subsidy into the hands of EU officials, but the process for judgement was not thought to be clear and persuasive.

Second, the global alliances among carriers put us difficult problems. As noted in the text, alliances are likely to make competition more active and increase passengers' benefits. But there is a possibility that it fosters worldwide oligopoly in international aviation, and if so, we will need someone or some authorities to keep on watching the behavior of players. It does not seem to be easy for us to agree with each other on the best regulator in this matter.

~~Japan, Korea and China are neighboring countries in the East Asian region and, in the first decade of 21 century, the air transport demand in this area may well achieve the highest growth in the world. Three governments should cooperate in order to try to solve these remaining problems.~~

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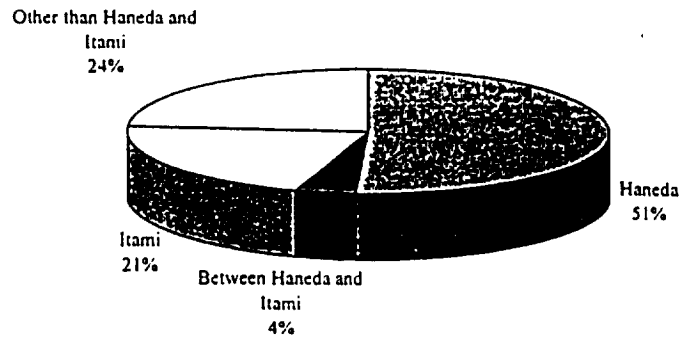


Figure 1. Passenger Shares of Haneda and Itami Airport

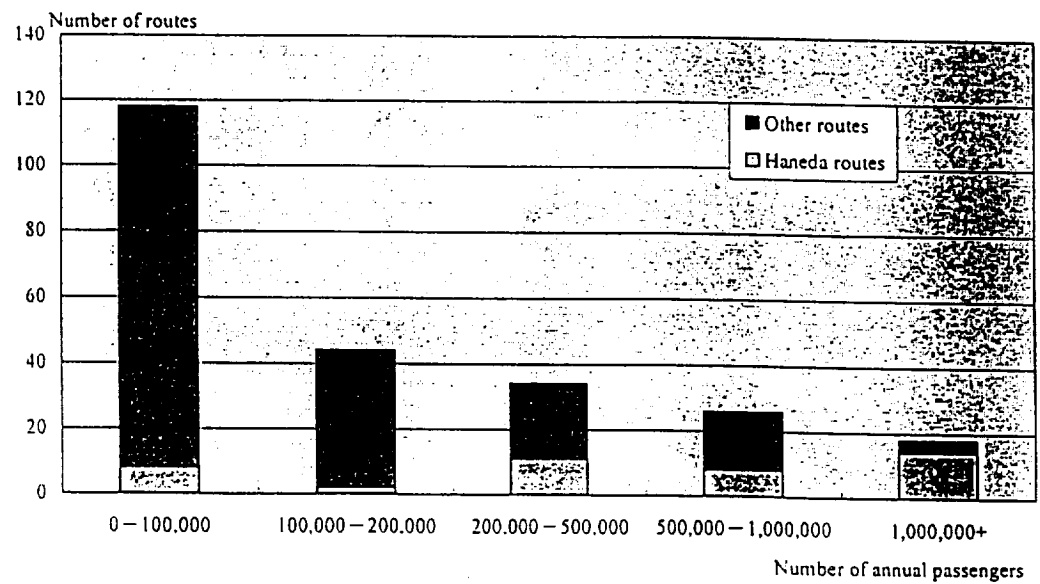
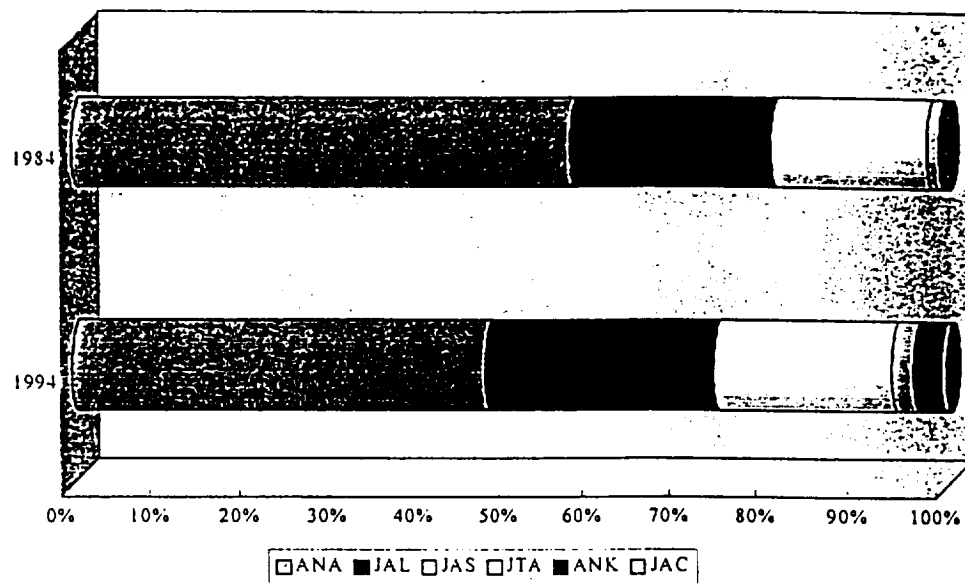


Figure 2. Route Structure of Air Transport in Japan



	ANA	JAL	JAS	JTA	ANK	JAC
1994	47.2%	26.7%	19.9%	2.5%	3.2%	0.5%
1984	57.4%	23.3%	17.2%	1.4%	0.7%	0.0%

Figure 3. Changes of Share in the Domestic Market

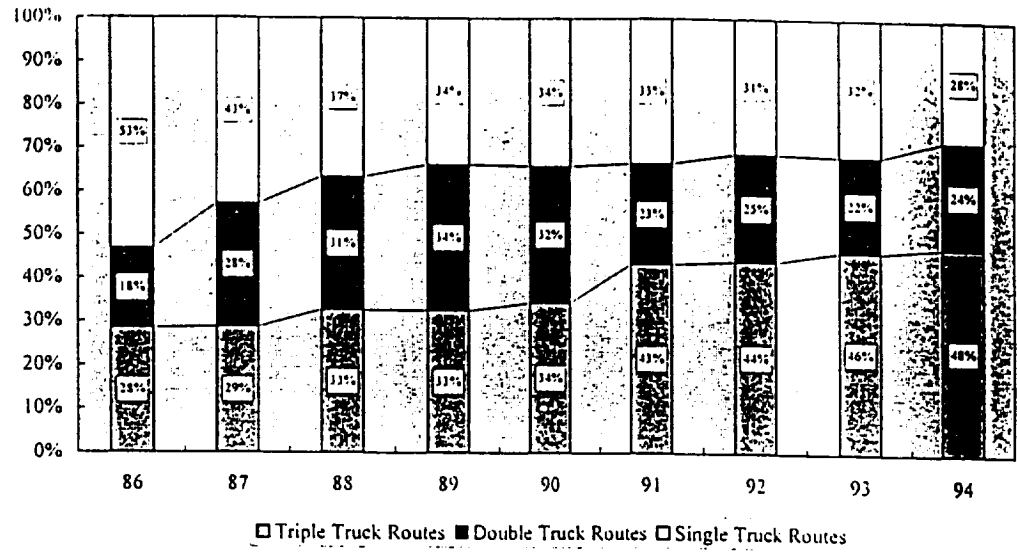


Figure 4. Passenger Share by Market Type

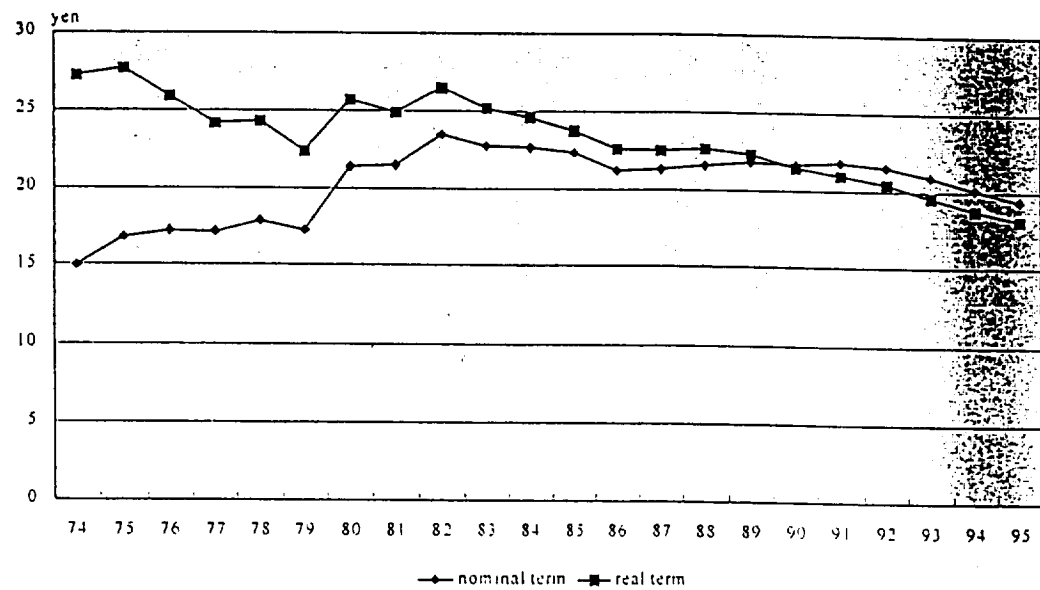
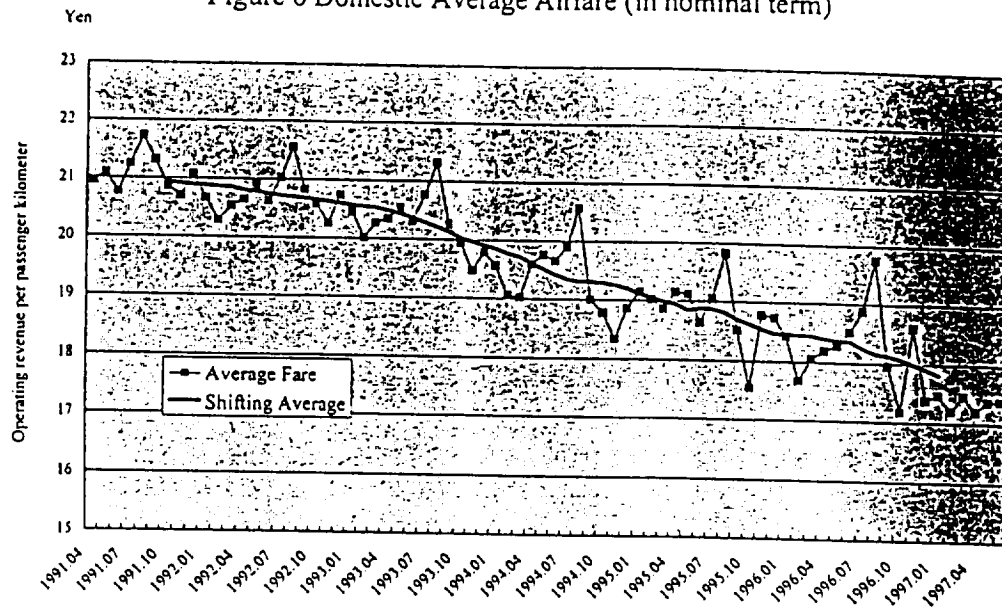


Figure 5. Trends in Average Airfares, 1974-1995

Note: calculated as total passenger revenue divided by total revenue passenger kilometers.



Figure 6 Domestic Average Airfare (in nominal term)



**AVIATION INFRASTRUCTURE PERFORMANCE AND AIRLINE COST:  
A STATISTICAL COST ESTIMATION APPROACH**

**Mark M. Hansen  
David Gillen  
Reza Djafarian-Tehrani**

Institute of Transportation Studies  
National Center of Excellence in Aviation Operations Research (NEXTOR)  
University of California at Berkeley

May, 1999

**Corresponding Author:** Mark Hansen  
107B McLaughlin Hall  
Berkeley, CA 94805  
Phone: 510-642-2880  
Fax: 510-642-1246  
e-mail: [hansen@ce.berkeley.edu](mailto:hansen@ce.berkeley.edu)

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Aviation Infrastructure Performance and Airline Cost: A Statistical Cost Estimation  
Approach  
-Abstract-

The relationship between the performance of the U.S. National Airspace System (NAS) and airline costs is examined by estimating airline cost functions which include NAS performance metrics as arguments, using quarterly data for 10 U.S. domestic airlines. Performance metrics that vary by airline and quarter are developed by applying factor analysis to seven underlying variables, including average delay, delay variance, and the proportion of flights which are cancelled. This analysis reveals that variation in the seven variables can be adequately summarized by three or fewer factors, which we term NAS performance factors. If three factors are used, they correspond to "delay", "variability", and "disruption". The first of these captures average flight departure and arrival delay. The second reflects the variance in delay, while the third is based on the incidence of situations in which operations become sufficiently irregular to require flight cancellations. In the two-factor representation, "variability" and "disruption" factors are essentially merged into an "irregularity" factor, while the one factor model blends "irregularity" with "delay". When the NAS performance factors are used as arguments in an airline cost function, the "disruption" factor is found to be positive and significant in the three-factor model, as is the "irregularity" factor in the two-factor model. No significant effect is found in the cost function with one performance factor. Using the estimated two- and three-factor models, we estimate the cost savings that would result if the NAS performance levels in each observation were improved to the highest level found in our data set, and find annual savings to be in the \$1.5-2 billion range. The estimates are fairly consistent with previous estimates of the cost of delay based on applying delay "cost factors" to the number of minutes of aggregate delay. On the other hand, our findings suggest that the main linkages between NAS performance and airline cost involve irregularity and disruption rather than the quantity of delay minutes.

## 1. Introduction

The need to understand and quantify the benefits of public and private investments in the National Airspace System (NAS) has never been greater. On the public side, Executive Order 12893, published in 1994, requires the Federal Aviation Administration (FAA) along with other federal agencies to conduct systematic analysis of benefits and costs of all infrastructure investments involving annual expenditures in excess of \$50 million. The analysis is to "quantify and monetize benefits and costs to the maximum extent possible (FAA, 1998)." Moreover, the FAA Acquisition Management System, published in 1997, mandates an "investment analysis" prior to the initiation of a new acquisition program, including, among other things, the identification of alternatives and assessments of their benefits and costs (FAA, 1998). Such analyses are required for a host of Air Traffic Management (ATM) and Communications-Navigation-Surveillance (CNS) programs through which FAA intends to modernize the NAS over the next two decades (FAA, 1999).

Private investments, particularly those by airlines in advanced avionics for new aircraft, are also getting closer economic scrutiny. According to Allen et al (1998), "the industry is getting to the point where the achievement of business case maturity may be more important than technical maturity." Business case maturity includes the ability to explicitly identify benefit mechanisms triggered by CNS/ATM investments, credible estimates of the dollar values flowing from these mechanisms, and explicit analysis of investment risk (Allen et al, 1998). The CNS/ATM Focused Team (C/AFT), whose membership includes airframe manufacturers, airlines, and the FAA, has been working since 1997 to develop and apply a methodology for developing such business cases.

While the need for benefit quantification is growing, industry stakeholders are also recognizing that the performance of the NAS is multi-dimensional, and therefore not adequately captured by traditional, delay-based, metrics. For example, the C/AFT has identified six categories of performance, including, in addition to delay, predictability, flexibility, efficiency, access, and cost of service (Alcabin, 1999). These concepts are considered to "define the elements of value to the scheduled airline business" as well as "the common criteria for developing economic models needed to predict benefits..." (Alcabin, 1999).

Taken together, these trends suggest that NAS investment analyses should consider, and attempt to monetize, the impacts of a proposed investment on multiple dimensions of NAS performance. Unfortunately, the state of practice falls far short of this ideal. Almost without exception, investments analyses and business cases consider only delay and direct cost savings when evaluating the benefit of a NAS improvement. For example, a recent business case for advanced data link (ATS Data Link Focus Group, 1999), considered to be a path-breaking effort within the industry, identifies four benefit categories. Two involve communication cost savings, one is increased availability of communication between aircraft and airline operations centers (this was guessed to be worth anywhere between \$16 and \$48 per flight), and the last category is delay cost savings (valued at \$25 per minute based on aircraft direct operating cost).

Thus, even as industry stakeholders recognize that NAS performance has many aspects, only delay is routinely monetized. Even here, however, there is ample room for skepticism about the procedures. Virtually all delay cost calculations involve nothing more than the application of a cost factor based on reported values for the average direct aircraft operating cost per block hour to quantities of delay measured in time units. For air transport aircraft, the cost factor is in the range of \$20-\$25 per minute. A few studies refine this figure by differentiating between delay taken at the gate, on the ground, and in the air (Odoni, 1995; Geissinger, 1989). Others extend the calculations by disaggregating expense by functional category, such as fuel, flight personnel, maintenance, and capital, and estimating how delay, portrayed as changes in the quantity of block hours, affects each one (Kostiuk et al, 1998).

The approaches to delay cost estimation share some strong assumptions that are rarely scrutinized or even acknowledged as such. These include that the cost of delay is an additive function of the cost of individual delay events, and that the cost of each event is a linear function of the duration of the delay (and perhaps the phase of flight in which it occurs). Such assumptions ignore the possibility that delay cost is non-linearly related to duration, is subject to combinatorial effects, and includes sizable indirect components.

It is probable that the cost of a delay varies nonlinearly with the duration of the delay. For example, one 40-minute delay is more costly than 40 one-minute delays. The 40-minute delay is far more likely to disrupt ground operations, gate assignments, crew schedules, and passenger itineraries. Conversely, airlines sometimes add delays to flights to, for example, avoid having a flight arrive at a hub in the middle of a departure bank. If this is rational behavior, then the relationship between cost and delay must not only be non-linear, but also non-monotonic.

Delay costs are also subject to combinatorial effects. The severity of the impacts noted above is likely to depend not only on the duration of delay to a specific flight but on the interaction of delays for many flights. This is particularly evident in a hub-and-spoke network in which flights are scheduled in connecting banks. If all the flights in an inbound bank are delayed by the same amount, then the effect may be far less severe than if half the flights are delayed by a larger (or even the same) amount.

Finally, the prevalence of delays may generate sizable indirect costs through airline adaptation behaviors. Carriers may take a variety of measures to make their operations more robust to delay. These include building more padding into scheduled block times, providing flights with additional fuel, and having extra aircraft, flight crew, and ground personnel available. While these measures decrease the cost of delays when they occur, they also increase costs of day-to-day operation. In this way the cost of delay may permeate throughout the entire cost structure of the airline in ways that are not tied to individual delays events.

Our limited ability to take these aspects of delay cost into account, combined with the nearly complete absence of information on how to place an economic value on other

dimensions of NAS performance, represent critical gaps in knowledge at a time when massive investments in the system are being contemplated. One might attempt to fill these gaps in a variety of ways. Simulation is one possibility. To address the questions under consideration here, a simulation would have to be highly detailed. It would need to capture how airlines respond on a real-time basis to operational irregularities and the cost implications of that response. The problem gets especially complicated when major adjustments such as rerouting of aircraft and reassigning crews are considered. While such a simulation may eventually be possible, it is beyond our present capabilities.

A second possibility is to systematically query airline personnel. For example, one might present dispatchers with different scenarios concerning the operation of their assigned flights throughout the day or month, and ask them to choose which scenarios are more desirable. If the scenarios were carefully chosen, this procedure would reveal the preferences of the participants, and thereby allow the estimation of utility functions whose arguments would be various dimensions of NAS performance. Such a study might yield very useful results, but is also subject to a number of objections. First, it is not clear how such a methodology could allow monetary valuation of NAS performance, since this would require participants to choose between scenarios that involve money as well as flight operations. Second, it is not obvious that dispatchers, or any other airline personnel, have a sufficiently global view of the airline's interest to make the correct choices. Finally, the results of such a study might be biased by principal/agent effects, with respondents making choices that are best for them rather than for the airline as a whole.

This paper focuses on a third approach, which is to estimate airline cost functions including NAS performance measures as arguments. Using published, quarterly, airline-level data, we estimate relationships between airline operating expense, outputs, factor prices, and other variables. Included among the latter are a set of variables, which we term "NAS performance factors," that quantify the airline's operational experience in the NAS during the quarter. By observing how these variables influence airline expense, we establish a direct empirical basis for translating various dimensions of NAS performance into monetary terms. Any quantifiable aspect of NAS performance can, in principle, be accommodated in this framework. Moreover, because relationships are derived from observed co-variation between performance variables and cost, the results entail a minimum of assumptions about the mechanisms involved.

This paper presents a first step in using cost estimation to assess the economic value of NAS performance. It employs a relatively small data set and, accordingly, a limited set of NAS performance variables and a simple form for the cost function. Nonetheless, it yields plausible results, including industry-wide estimates of the costs from "sub-optimal" NAS performance that can be compared with results of more conventional studies based on delay cost factors. This suggests that statistical cost estimation is a promising avenue for assessing the economic benefits of NAS improvements.

We proceed as follows. In the next section, we present our analytical framework. In Section 3, we describe and present results from our procedure for developing airline level NAS performance variables. Section 4 turns to the specification and estimation of our

cost model, which we then use, in Section 5, to estimate airline cost savings from improving NAS performance. Conclusions are presented in Section 6.

## 2. Analytical Framework

The cost function of a firm is defined as the lowest cost at which it can produce a given set of outputs,  $\bar{Y}$ , given the prices it pays for inputs,  $\bar{P}$ . Equivalently, it represents the cost of acquiring the optimal set of inputs,  $\bar{X}^*$ , given the outputs and prices. Thus we have:

$$COST_{it} = \bar{P}_{it} \cdot \bar{X}^*(\bar{Y}_{it}, \bar{P}_{it}) = C(\bar{Y}_{it}, \bar{P}_{it}) \quad (1)$$

where the subscript  $i$  denotes a particular firm (airline), and  $t$  identifies the time period. The cost function, like the production function, is a way of depicting the technology available to the firm, i.e. its ability to transform inputs into outputs. Implicit in (1) is that all airlines have the same technology, an assumption that could be relaxed by adding airline subscripts to the cost and conditional demand ( $\bar{X}^*$ ) functions.

Equation (1) can be considered a long-run cost function because it assumes that all inputs have been adjusted to their optimal levels. Some inputs, particular capital inputs, cannot be varied instantaneously. A short-run cost function relaxes the assumption of optimal capital stock by treating capital as a quasi-fixed factor and removing capital costs from the dependent variable. This results in capital being an argument in the short-run cost function. Thus we have:

$$SCOST_{it} = \bar{P}_{it} \cdot \bar{X}^*(\bar{Y}_{it}, \bar{P}_{it}, K_{it}) = S(\bar{Y}_{it}, \bar{P}_{it}, K_{it}) \quad (2)$$

where capital is excluded from the price and conditional demand vectors.

It has long been recognized that costs depend upon the nature and quality of airline outputs as well as the quantity. For example, airlines have been shown to have economies of density, whereby the cost for a given total output increased with the size of the airline's network. Several additional variables are included to capture such effects. These are incorporated into the vector  $\bar{Z}_{it}$ . This yields a short run cost function of the form  $O(\bar{Y}_{it}, \bar{P}_{it}, \bar{Z}_{it}, K_{it})$ . This form, as well as the long-run version in which capital is not an argument, has been widely studied in the airline economics literature (Caves et al, 1985; Gillen, Oum and Tretheway, 1990; Windle, 1991; Encaoua, 1991; and Hansen and Kanafani, 1989), and serves as the point of departure for the present study.

In this study we add one additional vector argument,  $\bar{N}_{it}$ , which characterizes airline  $i$ 's operational experience in the NAS during time period  $t$ . In general,  $\bar{N}_{it}$  is based on variables such as average delay, delay variance, and the proportion of cancelled flights. It can be viewed as the performance of the NAS from the standpoint of an individual airline. This is not to suggest that  $\bar{N}_{it}$  depends only on the performance of public aviation infrastructure; rather it derives from the interaction between that infrastructure and operational decisions taken by the airline. Both public and private investments in the NAS are primarily intended to change  $\bar{N}_{it}$  for the better.

Thus our analysis revolves around estimating the operating cost function  $O(\bar{Y}_{it}, \bar{P}_{it}, \bar{Q}_{it}, K_{it}, \bar{N}_{it})$ . The first four arguments are standard ones in the airline cost estimation literature. The last, which is the focus of our investigation, implies a relationship between NAS performance, measured at the airline level, and airline operating cost. In order to quantify that relationship, one must find a develop an  $\bar{N}_{it}$  vector which captures airline-level NAS performance in a compact, yet comprehensive, way. To this task we now turn.

### 3. NAS Performance Measurement

Our measures of NAS performance are derived from the operational experience of airlines using the NAS, as captured by such metrics as average delay, variability of delay, and flight cancellation rates. As noted previously, these measures do not only reflect the quality of service provided by the public aviation infrastructure, but also the airlines' ability to plan and manage their operations. Both of these factors depend on exogenous events, particularly weather, as well as the competence (and perhaps luck) of service providers and users. Thus, when we refer to high or low performance levels, we are not affixing credit or blame to either the FAA or the airlines, but rather assessing operational outcomes in which both, along with a host of exogenous factors, played a role.

We must quantify NAS performance by airline and quarter. To do so, results for thousands of flights must be summarized by a much smaller set of metrics. There is no uniquely valid way of doing this. One might, for example, base metrics on the flight, the flight complex, the day, or the airport-day. (To illustrate the last possibility, one could might categorize for a particular airline, airport, and day as "smooth", "mildly irregular", or "highly irregular", count the number of airport-days in each category, and use these as the performance metrics.) Here, we opted for the more conventional flight-based approach, reserving the others for subsequent work.

Even while confining ourselves to flight-based metrics, there is a huge number that might be employed. To keep the analysis tractable, we employed a two step approach. In the first step, we evaluated seven metrics for each airline and quarter in our data set. Next, we employed principal component analysis to collapse these metrics into a smaller number of factors, and calculated the factor scores for each airline and quarter. These factor scores were used to compose the  $\bar{N}_{it}$  vector used in the subsequent cost estimation.

The seven underlying metrics are defined in Table 1. The first two metrics pertain to delay, and are thus the most closely related to the conventional approach for measuring NAS performance. The third metric focuses on more extended delays and reflects the hypothesis that such delays may have qualitatively and quantitatively different impacts on costs. The next three metrics reflect variability in flight operations. The final metric reflects the incidence of conditions when operations become sufficiently irregular to result in flight cancellations. All of the metrics were evaluated by airline and quarter—for the 11 quarters extending from the winter of 1995 through the summer of 1997--using the



Airline Service Quality Program (ASQP) data base, which presents scheduled and actual departure times for every domestic flight of the top 10 U.S. carriers. Thus our data set includes 110 observations. Since we employ a log-linear cost function specification, and all metrics were consistently positive, logarithms of these metrics are used in the subsequent analysis.

As shown in Table 2, the seven performance metrics are highly intercorrelated. All correlations are greater than 0.4, and the majority are in excess of 0.6. This suggests the use of principal component analysis as a way of capturing most of the information contained in the seven performance metrics in a smaller number of variables. Principal component analysis identifies a set of factors--linear combinations of the original variables—which together account for as much of the total variation in the original data as possible. The factors are obtained by finding eigenvectors of the correlation matrix. The higher the eigenvalue, the greater the explanatory power of the associated eigenvector. By convention, each factor has zero mean and unit variance. By virtue of being eigenvectors, the factors are also mutually orthogonal.

The results of the principal component analysis of the NAS performance data are summarized in Table 3. The first component has high, positive, loadings on all seven factors and accounts for 72 percent of the total variation. The second factor, which accounts for about half of the residual variation, has positive loadings on the variance metrics and negative loadings on delay and unreliability. Thus airlines which score high on this factor tend to have unusually high delay variances combined with unusually low delay averages. The third factor explains 8 percent of the total variation, and has a high positive loading on flight cancellations and a negative loading on departure delay variance. Altogether, these factors explain about 94 percent of the variation in the total data set.

In principal component analysis, the standard procedure is to determine the number of factors to be extracted from the data, and then rotate these factors so that factor loadings are close to either 0 or  $\pm 1$ , in order to simplify their interpretation. In choosing the number of factors, one must make a judgment about when the additional variation explained by a factor is sufficient to justify retaining it. In the present case, we decided to confine our attention to no more than three factors, since none of the remaining ones accounted for more than 3 percent of the total variation. The choice between one, two, or three factors was more difficult. An oft-cited rule-of-thumb is to include only those factors which account for more than one Nth of the variation, where N is the number of variables in the data set. Applying this to the present case, we find that only one factor should be retained. On the other hand, this leaves out nearly 30 percent of the variation in the original data set, suggesting the possibility of adding a second or third factor. Rather than fixing on a single alternative, we chose to estimate cost models including one, two, and three NAS performance factors.

Varimax factor rotation was then performed on the two factor and three factor representations. The results appear in Table 3. In the two factor case, the first factor correlates more highly with the delay variables, including the average delays, average

delays over 15 minutes, and unreliability. The second factor has the highest loadings on the departure and arrival delay variances, the cancellation rate, and, like the first factor, average delays over 15 minutes. One might summarize this by terming the first factor "delay", and the second factor "irregularity". When three factors are used, the first one is virtually identical to that in the two factor case. The second factor is also quite similar, except that the loading on cancellation rate is considerably lower. The third factor has a very high loading on cancellation rate, along with some correlation with arrival delay variance and average delay over 15 minutes. The three factors might be described as "delay", "variability", and "disruption". A carrier with a high score on the first factor has flights that depart and arrive later (relative to schedule) than those of the average carrier. If the second factor score is high, then delays fluctuate more widely than average, while a high score on the third factor means that conditions in which flights must be cancelled are more prevalent than average.

Figures 1 and 2 present average factor scores for the one-factor analysis, by airline and quarter respectively. Figure 1 reveals that, using the one-factor analysis, the two carriers experiencing the best NAS performance (i.e. with the lowest factor score) are USAir and Southwest, while Delta, United, and TWA experience the worst performance. Figure 2 shows that the quarters with the worst NAS performance include the winters of 1996 and 1997, along with the summer and fall of 1996. Good quarters include the springs and summers of 1995 and 1997. While there is some seasonal pattern in the data, it is not particularly strong, as evidenced by the fact that two of the three summer quarters are among the best while the third is among the worst.

Figures 3 and 4 present airline and quarterly averages for the three factor analysis. These provide a more complete picture of NAS performance trends. We see that Southwest is the only carrier to be better-than-average for all three factors, while United is the only one to be below average for all three. A number of carriers feature performance far better than average for some factors and worse than average for others. For example, Northwest has relatively low delay (Factor 1), but high variability and disruption (Factors 2 and 3). In contrast, Delta has low disruption but high variability and delay. Because the factors are, by construction, orthogonal the lack of a consistent pattern in the airline factor scores is to be expected.

From Figure 4, we see that just two quarters—the spring and summer of 1995—have better than average performance on all three dimensions, while two others—fall, 1996 and winter, 1997—are consistently worse than average. We also see from Figure 4 that the horrific winter of 1996 was particularly bad from the standpoint of delay and disruption, but average from the standpoint of variability. A similar, but less pronounced pattern is seen in the winter of 1997, while in the winter 1995 only disruption was worse than average. Disruption is consistently less of a problem in the spring and summer quarters, as is delay except for 1996. Finally, there is some evidence of a secular trend to worse performance on the variability dimension: four of the first five months are above average in this respect, while each of the last six months is below average.

#### 4. Cost Model Specification and Estimation

We now consider the relationship between the airline-level NAS performance factors derived in Section 3 and airline operating cost, using the cost function framework explained in Section 2. To do this, we use the performance factors to compose the NAS performance vector,  $\bar{N}_{it}$ , which in turn is used as an argument for the cost function.

The airline cost estimation literature has evolved sophisticated techniques involving flexible functional forms combined with simultaneous estimation of cost and input share equations. Here, we opt for a simpler approach—based on the Cobb-Douglas form—for several reasons. First, our data set is comparatively small, extending over just 11 quarters for which ASQP data were readily available at the time of our analysis. This makes it important to conserve degrees of freedom by using models requiring few parameters. Second, our aim is not to fully reveal airline cost structure, but simply to assess the impact of NAS performance on airline costs. Finally, we find that a simple Cobb-Douglas model fits the data extremely well, suggesting that more complex model would provide little “value-added.”

The Cobb-Douglas form leads to the log-linear model specification:

$$\ln(TOC_{it}) = \alpha_0 + \alpha_i + \sum_j \beta_j \ln(Y_{jit}) + \sum_k \omega_k \ln(W_{kit}) + \sum_\ell \gamma_\ell \ln(Z_{\ell it}) + \kappa \ln(K_{it}) + \sum_m \lambda_m N_{mit} + \varepsilon_{it} \quad (2)$$

where  $TOC_{it}$  is operating expense for airline  $i$  in time period  $t$ ;  
 $Y_{jit}$  is the quantity of the output  $j$  for airline  $i$  in time period  $t$ ;  
 $W_{kit}$  is the factor price for input  $k$  for airline  $i$  in time period  $t$ ;  
 $Z_{\ell it}$  is the value of operating characteristic  $\ell$  for airline  $i$  in time period  $t$ ;  
 $K_{it}$  is working capital for airline  $i$  in time  $t$ ;  
 $N_{mit}$  is the value for NAS performance factor  $m$  for airline  $i$  in time  $t$ ;  
 $\varepsilon_{it}$  is a stochastic error term.

The specific variables included in the model are detailed in Table 4. Two outputs, revenue passenger miles, and “other”, are considered. The latter combines freight ton-miles, mail ton-miles and other miscellaneous outputs in a divisia index normalized so that this output is 1 for American Airlines in the first quarter of 1995. Three production factors, fuel, labor, and “materials”, are included. Fuel and labor prices are calculated using fuel expense per gallon and labor expense per employee respectively. The latter is somewhat imprecise because it does not take into account hours worked or employee classification (pilots versus flight attendants for example). As a proxy for “materials” price, we use the producer price index (PPI), which varies by quarter but not by airline. The three operational characteristics are average load factor, the number of points served, and scheduled departures. These variables capture qualitative features of an airline’s

output that are likely to influence cost. Our measure of airline capital stock is the sum of the airline's net asset value, working capital, and accounts receivable, minus accounts payable. The capital stock variable is subject to some error because of the rather arbitrary depreciation rules used by airlines. With the exception of the PPI, all of these data are obtained from the airline balance sheet data published in the Department of Transportation's Form 41 database.

As previously noted, we employ NAS performance factor scores to define the  $\tilde{N}_{it}$  vector. We estimate models in which this vector contains one, two, and three factor scores, employing the rotated factors. As a result of the rotation, the factors employed in the three models are all different from one another, as shown in Figure 3. By virtue of being factor scores, all have zero mean and unit variance. Also, because the factors are linear combinations of the logarithms of the seven original performance variables, they enter into the model in linear rather than log-linear form.

The specification of the intercept term,  $\alpha$ , is an important issue. As specified in (2), the model incorporates airline-specific intercepts, or airline fixed effects. Alternatively, one might assume a single intercept that applies to all airlines by eliminating  $\alpha_i$  from (2). When fixed effects are incorporated, they may absorb variation that is really due to other factors, particularly when analyzing short time series in which explanatory variables do not change very much for individual observations for the same airline. On the other hand, one could argue that individual airlines will tend to have higher or lower costs, all else equal, due to differences in productivity and other omitted variables. In the present context, we choose to include airline fixed effects because our focus is on the NAS performance variables. On the one hand, these variables do exhibit considerable intra-airline variation, mitigating the absorption problem. On the other hand, consistent inter-airline differences in these variables may reflect differences in managerial competency that carry over into other areas, creating the possibility of spurious results if the dummies are excluded. We employ American Airlines as the "baseline" carrier whose fixed effect is forced to zero.

In order to efficiently estimate the model, it is desirable to account for the expected correlation between stochastic errors for observations pertaining to particular airlines. We do this by allowing first order correlation between observations for the same airline. Thus we have:

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + v_{it} \quad (3)$$

where  $v_{it}$  is the component of the error term which is independently and identically distributed.

The model was estimated using the two-step Prais-Winsten (1954) method, in which  $\rho$  is estimated by performing regression on the OLS residuals, and the model is then re-estimated using the transformation  $\tilde{V}_{it}^* = \tilde{V}_{it} - \hat{\rho}\tilde{V}_{it-1}$ , where  $\tilde{V}_{it}$  is the vector of dependent and independent variables for airline  $i$  and time period  $t$ , to eliminate the autocorrelation. To maintain degrees of freedom, the first observations in the time series

are included, but multiplied by the factor  $\sqrt{1 - \rho^2}$  to maintain homoskedasticity. This estimation method has been reported to be as efficient as full maximum likelihood estimation in simulation experiments (Johnson, 1984).

## 5. Estimation Results

Table 5 summarizes our estimation results for the cost models with one, two, and three NAS performance factors. All three models have very good fits, with  $R^2$  values in excess of 0.99. Coefficient estimates are of the expected sign, and most are significant at either the 5 percent or 10 percent level. The estimates are also, for the most part, quite consistent across the three models. As anticipated, the airline fixed effects absorb persistent inter-airline differences, reducing some of the other coefficients. To illustrate, consider the cost impact of “scaling up” an airline by increasing its outputs, departures, number of points served, and capital stock by the same proportion. According to the model a 1 percent scale-up would increase cost by  $\beta_1 + \beta_2 + \gamma_1 + \gamma_2 + \kappa$  percent. On the basis of the estimates this sum ranges from 0.79 to 0.88 percent, implying fairly strong returns to scale. On the other hand, there is a fairly strong positive correlation between the magnitude of an airline’s fixed effect and its scale of operation: Alaska, America West, and TWA have the smallest fixed effects, while American, Delta, and United have the largest. This suggests that some of the cost impact of scale-up has been shifted from the scale coefficients themselves to the airline fixed effects.

Similarly, the estimate for the labor factor price coefficient is somewhat less than expected. This may also be caused by the fixed effects, or error-in-variables for the reasons explained in Section 4. Nonetheless, the estimated cost function is approximately homogenous of degree 1 in factor prices ( $\omega_1 + \omega_2 + \omega_3 \cong 1$ ) as predicted by economic theory, with the discrepancies well within the standard errors of the factor price coefficients. Error-in-variables and the presence of fixed effects can also explain the small and insignificant (though correctly signed) estimate of the capital stock variable.

Turning now to the focus of our inquiry, we find that, in the one factor model, the impact of the NAS performance metric has the expected sign, but is statistically insignificant. In both the two and three factor models, however, one of the factors has the correct sign and is highly significant. In the two factor model, it is the second factor, which we termed “irregularity” in the earlier discussion, which has the dominant effect. In the three factor model, the key factor is disruption. Recall that, in three factor model, the second and third factors, “variability” and “disruption,” are essentially a decomposition of the second factor, “irregularity”, in the two factor model. Thus the results are quite consistent, and reveal that it is the “disruption” component of “irregularity” that is the main cost driver. These effects are apparently lost in the one-factor model because they are subsumed in a single metric which also contains performance dimensions, such as average delay, that do not strongly influence cost. It is ironic that conventional investment analyses rely almost exclusively on these latter, seemingly unimportant, dimensions of NAS performance.

To assess the magnitude of the link between cost and NAS performance implied by our results, recall that the factors are standardized variables, and thus have unit variance. Therefore, a one unit change in a factor corresponds to change by one standard deviation. From the estimates, we see that such a change in either the “irregularity” factor in the two-factor model or the “disruption” factor in the three-factor model will cause a change in operating cost of roughly 1.5 percent. Put another way, we estimate that, in either of these cases, a relatively good factor score of one standard deviation below the mean would result in costs about 3 percent lower than a relatively bad score of one standard deviation above the mean.

In interpreting these results, it is important to remember that they reflect statistical rather than accounting relationships. Thus, in the three factor model, the strong impact of the “disruption” factor, whose highest correlate is the flight cancellation rate, does not mean that canceling flights in and of itself is an important cost driver. Rather, the cancellation rate should be viewed as an indicator for the incidence of highly degraded operating conditions, in which there are many flights with high delays, heavily corrupted flight complexes, large numbers of stranded passengers, and so on. It is probably these conditions, rather than the specific act of canceling a flight, which generate the cost impact.

## 6. Potential Benefits from Improved NAS Performance

In this section, we employ the estimation results presented in Section 5 to estimate the potential gains, in terms of reduced airline operating cost, from improved NAS performance. The estimates we present are, in a very rough way, comparable to estimates of the cost of delay to U.S. airlines, such as those reported by Citrenbaum (1998), the FAA Airline Policy Office (1995), Odoni (1995), Geissinger (1989), and several others. Our estimates differ from these others in two important ways, however. First, they are not based on delay but on the broader concept of NAS performance. Second, they are based on cost comparisons involving a scenario in which performance is substantially improved, but delay is not eliminated. Thus, whereas the studies cited estimate the cost savings from the impossible feat of reducing delay to zero, here we estimated the savings from a conceivable, albeit dramatic, improvement in NAS performance.

To ensure that the hypothetical improvement is realistic, we base it directly on the performance levels observed within our data set. Specifically, we calculate, for each of our 110 observations, the quantity  $\sum_m \lambda_m N_{mit}$ , as defined in (2), which represents the total contribution (which may be positive or negative) of NAS performance to  $\ln(TOC_{it})$ . Let  $i^*$  and  $t^*$  be the airline and time period for the observation, which we term the “reference observation”, in which this contribution is the most negative. Then, for any other observation, we compute the cost savings that would result from changing the performance vector for that observation,  $\tilde{N}_{it}$ , to  $\tilde{N}_{i^*,t^*}$ . Since we have about 100 observations, this procedure in effect considers a scenario in which NAS performance, measured at the airline, quarterly level, is consistently at the top 1 percent of what is presently experienced.

We carried out this procedure for both the two-factor and three-factor models. In each case, the reference observation was found to be Southwest Airlines in the 3<sup>rd</sup> quarter of 1995. Table 6 compares the “faw” performance metrics for this observation with sample means over all 110 observations, revealing the magnitude of performance change being hypothesized. The reference cancellation rate and delay variances are more than 50 percent below the corresponding sample means. For the other metrics, the differences are less pronounced although still considerable. On the whole, the comparison confirms that  $\bar{N}_{faw}$  represents a marked improvement over present-day conditions, but not an unreachable ideal.

Table 7 summarizes the cost savings from the improved performance scenario. Estimated annual operating cost savings from improving NAS performance are in the \$1.5-\$2 billion range. The lowest estimate is \$1.3 billion in 1995, based on the three-factor model, while the two-factor model applied to 1997 yields the highest estimate--\$2.3 billion. In general, savings estimated using the two-factor model are somewhat greater, as are those for the more recent years. This reflects the trend toward lower performance levels shown in Figure 4. The distribution of savings among airlines is naturally correlated with carrier size, with the largest airlines saving several hundred million per year, and the smallest ones about a tenth of that. Carrier savings also reflect their baseline performance levels, since those with poorer performance have more to gain.

For the reasons explained previously, these estimates are only roughly comparable to previously published ones of the cost of delay. Nonetheless, the latter offer useful benchmarks. The most recent published estimate, due to Citrenbaum and Juliano (1998), places the total direct operating cost of delay to air carrier and air taxi operators at \$0.8 billion in 1996. However this estimate is derived solely from comparisons between actual and scheduled gate-to-gate time, and thus does not consider costs of departure delays nor the phenomenon of schedule padding. Earlier FAA estimates (Aviation Policy Office, 1995) are based on arrival delays instead of gate-to-gate delays, and yield annual figures of \$2.5 billion, in current year dollars, throughout the early 1990s. Geisinger (1989), disaggregates delay by phase of flight and applies different cost factors for each phase, and obtained a cost of \$1.8 billion in 1986 (using the ATA composite index, this equates to \$2.5 billion in 1997). Odoni (1995), places the cost of delay, non-optimal flight trajectories, and flight cancellations to airlines in the \$2-4 billion range in 1993. Our figures of \$1.5-\$2.3 billion clearly fall within the range of these estimates. However it must be reiterated, unlike the other estimates, ours are based on a comparison with a realistic performance scenario rather than a perfect one. In that respect, our results suggest a greater potential saving from attainable performance improvements than the prior studies.

## 7. Conclusions

Our results support the view, suggested by several earlier studies, that improvements in the performance of the NAS can generate billions of dollars in annual cost savings. Unlike previous work, however, the estimates presented here derive from observed

covariation between airline expenditures and NAS performance levels. As a result, they do not rest on the strong and implausible assumptions required to calculate costs from quantities of delay, nor even on the assumption that delay is the critical cost driver. It is reassuring that such a fundamentally different methodology yields potential savings of a comparable magnitude.

Despite this agreement as to the "bottom line" our study presents a qualitatively different view of the link between NAS performance and airline cost. Of the performance metrics considered, we find quantities of delay to be among the least important. Instead, we find the critical cost drivers to be the levels of irregularity and disruption in the system. If we had to choose a single metric to track this dimension, it would be the flight cancellation rate rather than the average delay per flight. This may have significant implications for how NAS investments should be prioritized. In general, investments that increase the "robustness" of the system by preventing "all hell from breaking loose" appear to be more promising than those leading to incremental delay reductions in a broader range of conditions.

Methodologically, this study points to the role of statistical cost modeling as a means of translating the emerging, multidimensional, view of NAS performance into improved capability for investment analysis. Any dimension of NAS performance that can be measured at the airline level can, in principal, be related to airline cost using the methods set forth here. The only practical limitation is that the impact be strong enough to be detectable through the statistical noise. As data accumulates, our detection capability will improve.

As previously noted, there are other approaches to representing NAS performance that may more aptly capture cost impacts. One approach would be to categorize days, or airport days, in terms of their regularity and base performance metrics on the number of days in each category. Another would be to categorize total delay minutes according to type of flight, phase of flight, duration, and other factors and then develop metrics that summarize how delay is distributed across these categories. Other investigative approaches, including structured questioning of airline decision-makers and detailed simulations of airline operations, may also be of value. Such work may ultimately enable analyses of public and private investments in aviation infrastructure which capture their true benefits.



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**TABLE 1. PERFORMANCE METRIC DEFINITIONS**

<b>Variable (in Log form)</b>	<b>Definition</b>
Average Arrival Delay	Difference between scheduled and actual arrival time, averaged over all flights.
Average Departure Delay	Difference between scheduled and actual departure time, averaged over all flights.
Average >15 min Arrival Delay	Sum of all arrival delays in excess of 15 minutes, divided by total number of flights.
Arrival Delay Variance	Variance of the difference between scheduled and actual arrival time.
Departure Delay Variance	Variance of the difference between scheduled and actual departure time.
Unreliability	Proportion of flights with an arrival delay over 15 minutes.
Cancellation Rate	Proportion of flights cancelled.

**TABLE 2. RESULTS OF PRINCIPAL COMPONENT ANALYSIS**

<b>Variable (in Log form)</b>	<b>Factor 1</b>	<b>Factor 2</b>	<b>Factor 3</b>
Average Arrival Delay	0.85468	-0.46316	-0.05345
Average Departure Delay	0.86167	-0.31608	0.07645
Average >15 min Arrival Delay	0.98444	0.02062	-0.03112
Arrival Delay Variance	0.81784	0.51105	-0.08456
Departure Delay Variance	0.77662	0.38233	-0.42532
Unreliability	0.91327	-0.31949	-0.02627
Cancellation Rate	0.70281	0.31987	0.61739
Proportion of Variance Explained	0.7203	0.1324	0.0828
Cumulative Proportion	0.7203	0.8527	0.9355

**TABLE 3. ROTATED FACTOR PATTERNS FOR ONE, TWO, AND THREE FACTORS**

Variable (in Log form)	One Factor	Two Factors		Three Factors		
	Factor 1	Factor 1 "Delay"	Factor 2 Irregularity"	Factor 1 "Delay"	Factor 2 "Variability"	Factor 3 "Disruption"
Average Arrival Delay	0.85468	0.84848	0.34994	0.84157	0.24310	0.28441
Average Departure Delay	0.86167	0.94280	0.23688	0.94150	0.21837	0.11721
Average > 15 min Arrival Delay	0.98444	0.71120	0.68099	0.70453	0.58051	0.37035
Arrival Delay Variance	0.81784	0.25679	0.92957	0.24960	0.82240	0.44559
Departure Delay Variance	0.77662	0.31348	0.80687	0.31927	0.90509	0.09532
Unreliability	0.91327	0.88880	0.38233	0.88504	0.32591	0.21751
Cancellation Rate	0.70281	0.30136	0.71094	0.27235	0.25557	0.91539
Proportion of Variance Explained	0.7203	0.4514	0.4014	0.4447	0.3015	0.1892
Cumulative Proportion	0.7203	0.4514	0.8527	0.4447	0.7462	0.9355

**TABLE 4. COST ESTIMATION VARIABLE DESCRIPTIONS**

<b>Variable</b>	<b>Definition</b>
QUARTER	Quarter of year (1=Winter, 2=Spring, etc.)
TIND	Time counter (1 for 1Q 95, 2 for 2Q 95, ..., 11 for 3Q 97)
ALF	Average load factor (revenue passenger miles/revenue seat miles)
IDO	Index of output other than passenger miles (cargo, freight, etc). Normalized to American Airlines in 1Q, 1995.
TOC	Total operating cost for quarter (\$)
RPMS	Revenue passenger miles (000)
WAV	Total labor expense per employee (\$)
WFUEL	Fuel expense per gallon (\$)
WMAT	Produce price index (proxy for price for materials and services)
WK	Working capital (\$)
SDEP	Number of scheduled flights
BASE	Number of points served
CARRIER	Carrier code
YY	Year

TABLE 5. COST FUNCTION ESTIMATION RESULTS

Variable (Associated Parameter)	One-Factor Model			Two-Factor Model			Three-Factor Model		
	Estimate	Std. Err.	t-stat. <sup>1</sup>	Estimate	Std. Err.	t-stat. <sup>1</sup>	Estimate	Std. Err.	t-stat. <sup>1</sup>
Intercept ( $\alpha_0$ )	10.087	1.086	9.291	9.585	1.059	9.055	9.480	1.050	9.026
AA Fixed Effect ( $\alpha_{AA}$ )	--	--	--	--	--	--	--	--	--
AS Fixed Effect ( $\alpha_{AS}$ )	-0.724	0.129	5.618	-0.594	0.125	4.746	-0.573	0.124	4.628
CO Fixed Effect ( $\alpha_{CO}$ )	-0.208	0.069	3.010	-0.179	0.067	2.673	-0.175	0.067	2.626
DL Fixed Effect ( $\alpha_{DL}$ )	-0.048	0.065	0.738	-0.055	0.061	0.900	-0.050	0.060	0.821
HP Fixed Effect ( $\alpha_{HP}$ )	-0.551	0.104	5.322	-0.453	0.101	4.496	-0.442	0.100	4.445
TW Fixed Effect ( $\alpha_{TW}$ )	-0.430	0.088	4.862	-0.362	0.086	4.205	-0.354	0.085	4.151
UA Fixed Effect ( $\alpha_{UA}$ )	-0.064	0.034	1.883	-0.054	0.033	1.668	-0.063	0.033	1.926
US Fixed Effect ( $\alpha_{US}$ )	-0.067	0.121	0.550	-0.054	0.116	0.469	-0.058	0.114	0.505
WN Fixed Effect ( $\alpha_{WN}$ )	-0.366	0.147	2.490	-0.336	0.137	2.459	-0.331	0.134	2.460
NW Fixed Effect ( $\alpha_{NW}$ )	-0.301	0.077	3.893	-0.294	0.074	3.962	-0.290	0.073	3.964
RPMS ( $\beta_1$ )	0.431	0.144	2.990	0.424	0.137	3.099	0.441	0.135	3.261
IDO ( $\beta_2$ )	0.102	0.020	5.001	0.107	0.019	5.697	0.108	0.018	5.842
WLABOR ( $\omega_1$ )	0.298	0.044	6.772	0.275	0.043	6.453	0.261	0.043	6.104
WFUEL ( $\omega_2$ )	0.192	0.037	5.168	0.202	0.035	5.731	0.199	0.035	5.715
WMAT ( $\omega_3$ )	0.710	0.393	1.807	0.557	0.384	1.452	0.648	0.384	1.690
ALF ( $\gamma_1$ )	-0.341	0.183	1.870	-0.319	0.174	1.832	-0.288	0.174	1.659
DEPS ( $\gamma_3$ )	0.089	0.160	0.560	0.162	0.151	1.074	0.156	0.149	1.051
POINTS ( $\gamma_2$ )	0.195	0.089	2.189	0.199	0.084	2.385	0.202	0.082	2.451
WK ( $\kappa$ )	-0.029	0.028	1.057	-0.032	0.027	1.203	-0.031	0.027	1.163
NAS PERFORMANCE Overall" ( $\lambda_1^{(1)}$ )	0.005	0.003	1.497	--	--	--	--	--	--
NAS PERFORMANCE Delay" ( $\lambda_1^{(2)}$ )	--	--	--	-0.003	0.003	1.015	--	--	--
NAS PERFORMANCE Irregularity" ( $\lambda_2^{(2)}$ )	--	--	--	0.016	0.005	3.273	--	--	--
NAS PERFORMANCE Delay" ( $\lambda_1^{(3)}$ )	--	--	--	--	--	--	-0.003	0.003	0.967
NAS PERFORMANCE Variability" ( $\lambda_2^{(3)}$ )	--	--	--	--	--	--	0.007	0.006	1.103
NAS PERFORMANCE Disruption" ( $\lambda_3^{(3)}$ )	--	--	--	--	--	--	0.013	0.004	3.533
REGRESSION R <sup>2</sup>	.9983			.9988			.9988		
AUTOCORRELATION COEFFICIENT ( $\rho$ )	.3017			.1857			.1674		

1. t-statistics in bold are significant at the 10% level. t-statistics in *bold italics* are significant at the 5% level.

TABLE 6. PERFORMANCE METRICS VALUES, SAMPLE MEAN AND IMPROVED PERFORMANCE SCENARIO

Variable	Sample Mean	Improved Performance Scenario*
Average Arrival Delay**	8.26 min	6.71 min
Average Departure Delay**	8.56 min	4.61 min
Average > 15 min Arrival Delay	9.26 min	5.86 min
Arrival Delay Variance	804 min <sup>2</sup>	350 min <sup>2</sup>
Departure Delay Variance	714 min <sup>2</sup>	261 min <sup>2</sup>
Unreliability	0.21	0.19
Cancellation Rate	0.0207	0.0082

\*Based on Southwest Airlines, 3<sup>rd</sup> Quarter 1995

\*\*Averages are based on all flights, including those with "negative" delay

TABLE 7. ESTIMATED ANNUAL BENEFITS FROM IMPROVED NAS PERFORMANCE, IN MILLIONS

Airline	Two-Factor Model			Three-Factor Model		
	1995	1996	1997*	1995	1996	1997*
American	\$404	\$470	\$600	\$301	\$331	\$460
Alaska	14	25	31	13	21	30
Continental	167	190	208	143	154	152
Delta	278	355	373	135	191	172
America West	30	49	47	26	41	30
Northwest	264	302	281	235	271	217
TWA	95	116	108	82	118	96
United	294	408	365	255	355	322
USAir	109	203	208	140	220	221
Southwest	22	39	30	27	38	32
TOTAL	1676	2158	2253	1357	1740	1733

\*Annual estimated based on first three quarters of 1997



Figure 1. Average Factor Score, One Factor Analysis, by Airline

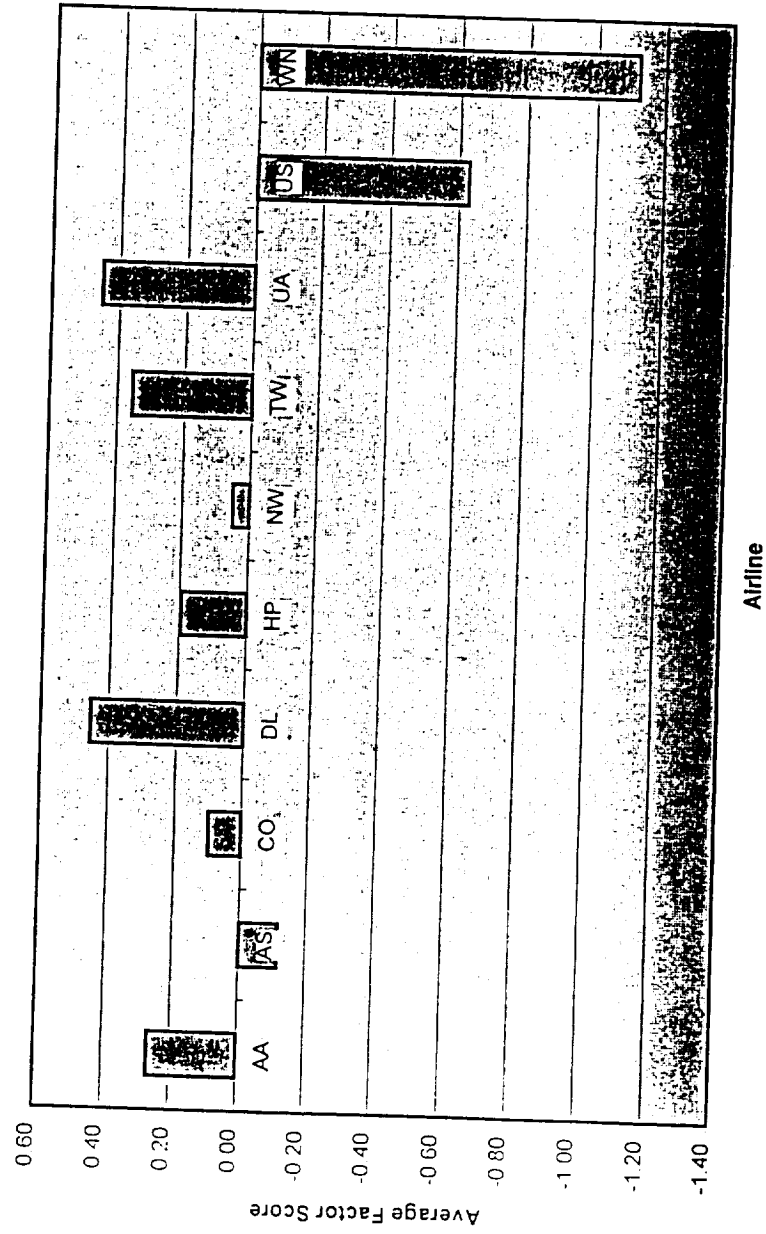


Figure 2. Average Factor Score, One Factor Analysis, by Quarter

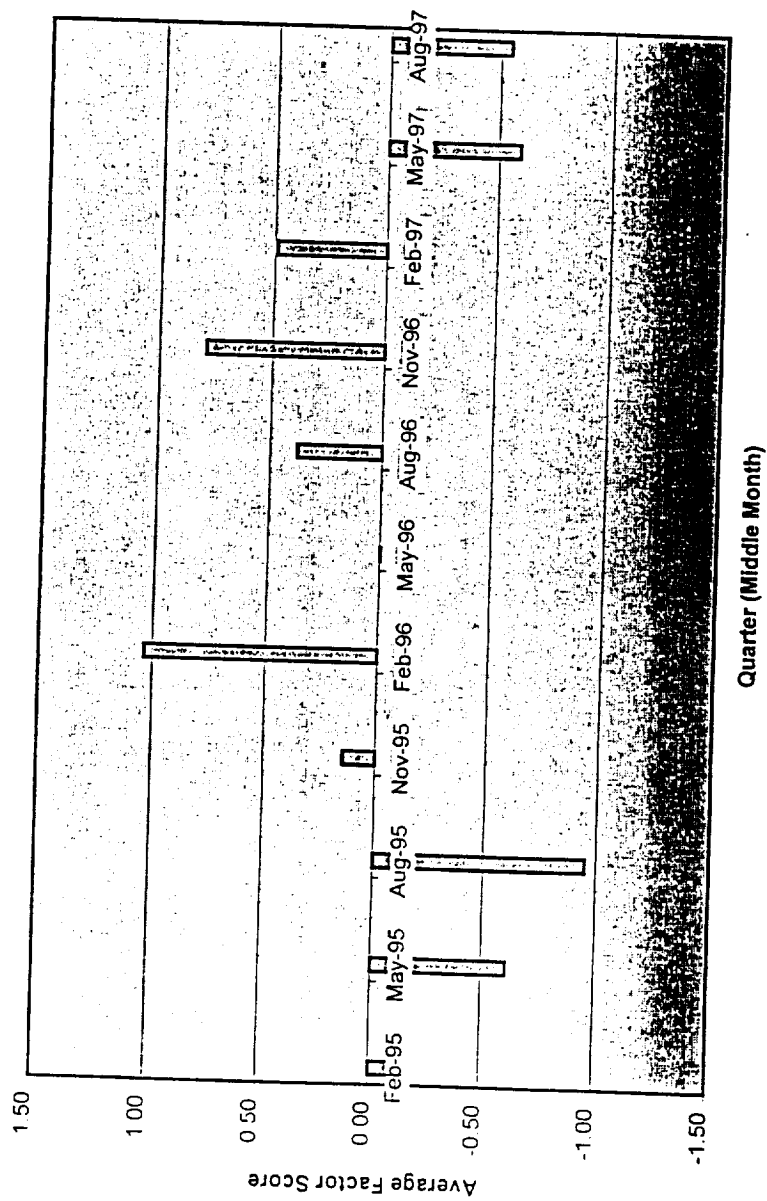


Figure 3. Average Factor Score, Three Factor Analysis, by Airline

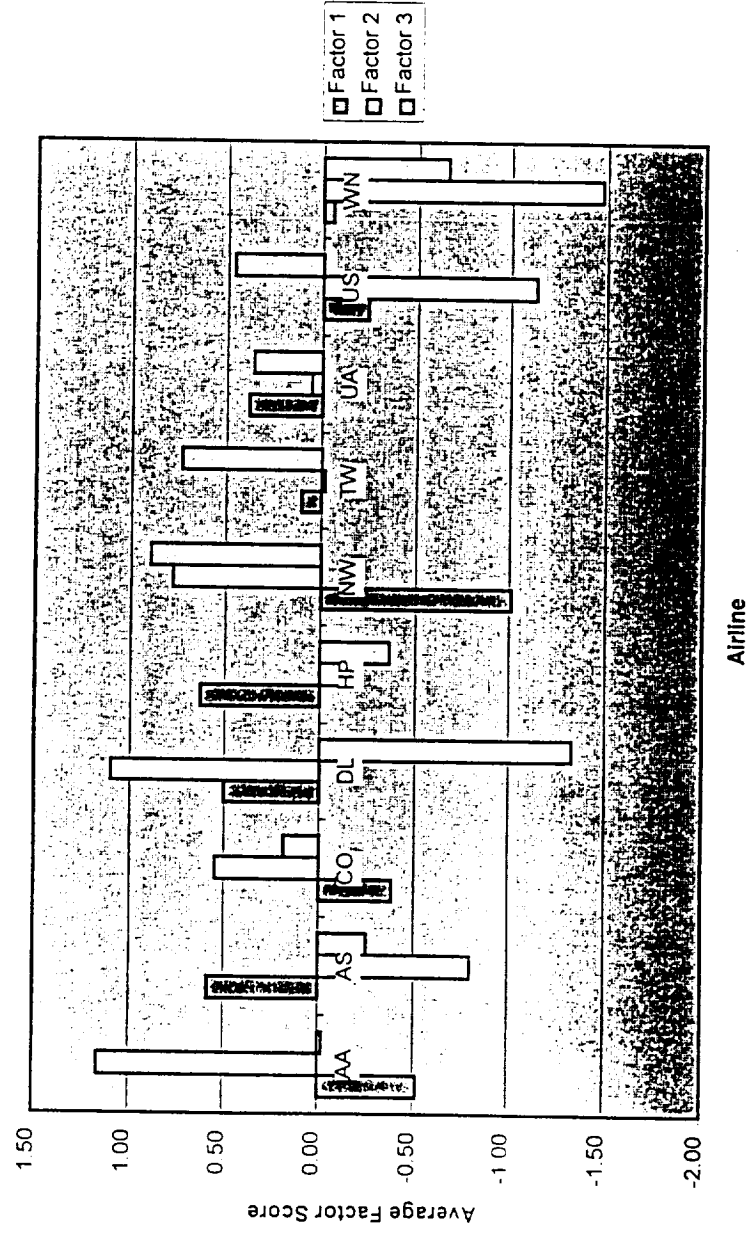
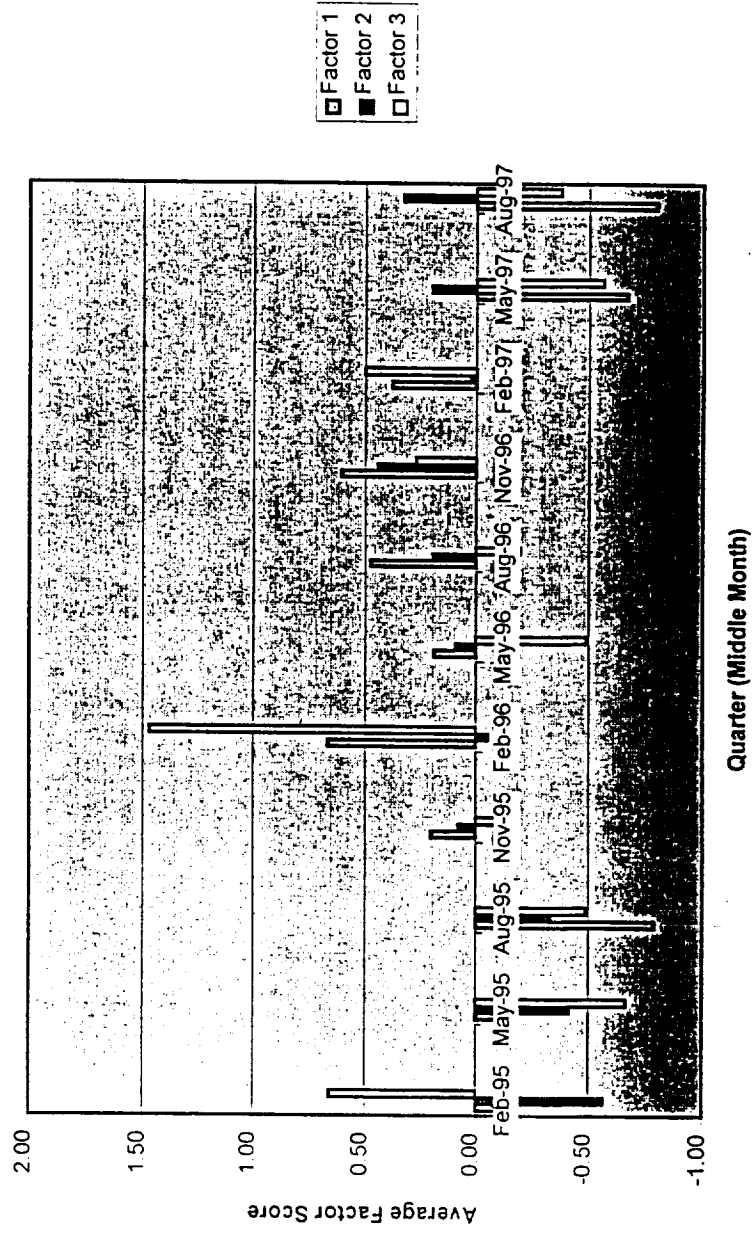


Figure 4. Average Factor Score, Three Factor Analysis, by Quarter



# Relative Efficiency of European Airports

Eric Pels\*, Peter Nijkamp\*, Piet Rietveld\*

Free University Amsterdam, Department of Regional Economics,  
de Boelelaan 1105, 1081 HV Amsterdam, Netherlands.

Email: apels@econ.vu.nl.

## Abstract

Using data envelopment analysis, efficiency ratios for European airports are determined. It appears that most airports are operating under increasing returns to scale. This is also reflected in the most productive scale size determined for the airports.

Keywords: airports, most productive scale size, data envelopment analysis

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\* Also affiliated to the Tinbergen Institute, Keizersgracht 482, 1017 EG Amsterdam.

## 1 Introduction

Recently, a number studies have been published on the measurement of airport performance; see e.g. Gillen and Lall (1997, 1998) for a non-parametric approach using data envelopment analysis, Hooper and Hensher (1997) for an analysis using total factor productivity and Tolofari et al. (1990) for an estimation of translog cost functions for British airports. This interest is caused by two circumstances: (i) the deregulation of the aviation market has stimulated the development of reliable performance measurements, since airlines operate in a highly competitive market and cannot pass the higher operating costs at inefficient airports onto the passengers (see Gillen and Lall, (1997), and (ii) the growth in the number of passengers raises the question whether this growth should be accommodated at existing airports or at new airports. This issue requires insight into the operating characteristics and performance of airports.

The estimation of cost functions allows for the testing of several hypotheses concerning economies of scale and the technology concerned (see e.g. Tolofari et. al. (1990)). As input prices are rather volatile over time, estimation of a longer term cost function becomes rather difficult. Moreover, input prices, if available, can differ significantly (in the way they are collected and reported) in space. Data envelopment analysis (DEA) does neither require knowledge on the input prices nor assumptions concerning the production technology or on the behavior of actors (e.g. cost minimization). The only assumption is that the production possibility set is convex. Using DEA one can get either input or output oriented efficiency measures for decision-making units (dmu-s)<sup>1</sup>. DEA also allows for a determination of the most productive scale size (mpss). At mpss, the average productivity is maximized; it represents the maximum productivity for any given input-output combination. Using the same technique it is also possible to determine whether a dmu operates under increasing, constant or decreasing returns to scale.

The DEA approach mentioned above provides a "measurement" of inefficiency (the "Farrell approach") rather than an "explanation" of inefficiency (the "Leibenstein approach") (Button and Weyman-Jones, 1994). An airport can be labeled as inefficient for different reasons. First, there are "indivisibilities". An expansion of the runway system will, in most cases, automatically create an over-capacity, since the length of a (new) runway is mainly determined by the landing (or take off) weight and speed of the aircraft using that runway. It may be necessary to construct a new runway, but due to technical (and safety) requirements, it may not be possible to make its capacity fit the expected (additional) demand. To a lesser extent the same holds true for terminals. Second, there are government regulations (e.g. limits to the hours of operations, noise contours) and limiting physical circumstances (e.g. fog and wind) under which the airports operate. For example, Amsterdam Airport Schiphol covers a (relatively) large area, also because of the noise contours imposed by the authorities. Schiphol has 4 runways in use, which, due to various weather conditions and strict regulations, have only a limited use. These two causes of inefficiency do clearly not fall under the control of the airport

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<sup>1</sup> By using the term dmu Charnes et al. (1978) emphasize that their interest lies in the decisions made by non-profit organizations rather than the (in theory) profit maximizing firms.

management, but on the other hand may not fully explain the inefficiency; airports can also be inefficient because the operators do not have an incentive to work as effectively as they could, e.g. if airports are government controlled. Although the DEA approach used does not require any assumption on the behavior of the actors involved, it is possible that, next to the (pure technical) inefficiencies described above, X-inefficiency also is important<sup>2</sup>. In this paper we are primarily concerned with the measurement of inefficiency. Gillen and Lall (1997) first measure inefficiency using DEA, and then explain inefficiency in a Tobit-analysis. We do not have sufficient data to explain any differences in efficiency in this way.

Inefficiency can also be measured using the stochastic production frontier method. This is a parametric method, and assumptions on the production technology are necessary. Inefficiency can be measured and explained simultaneously, in contrast to an ad hoc explanation of the DEA inefficiency measures. However, in contrast to the DEA, specific assumptions concerning the production technology are necessary.

The purpose of this paper is to measure the relative inefficiency of European airports and to indicate, given the prevailing input combinations, the maximum productive scale size for each airport. This scale size is the optimal configuration at the current input mix (i.e. if an airport were to change its technology, the maximum productive scale size would also change).

The outline of the paper is as follows. In section 2 the concept of mpss will be described. Section 3 contains a short description of DEA and the empirical results are presented in section 4. In Section 5 the inefficiency measures from section 4 are compared to the inefficiency measures from a stochastic production frontier analysis. Section 5 offers concluding remarks.

## **2      *Most Productive Scale Size***

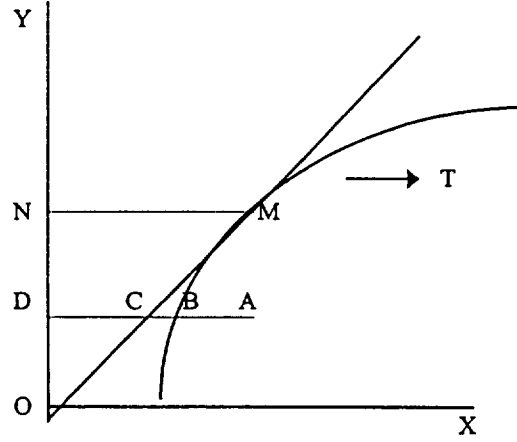
In this paragraph we provide a concise description of the concept of most productive scale size. For a more elaborate exposition the interested reader is referred to e.g. Banker and Thrall (1992) and Banker (1984). Using a minimum cost mix of inputs one can determine an optimal scale of a firm. This optimal scale depends on the prevailing input and output prices. Hence knowledge of the prevailing prices is required. Moreover, prices can be more volatile than the technology used. When one is interested in the performance of a decision-making unit over a longer period (or when prices are not available), the (pure) technical relation between inputs and outputs becomes interesting. One can look at returns to scale, and, associated with that, at the most productive scale size (mpss) at a given input-output mix<sup>3</sup>. The mpss for a given input-output mix is "the scale size at which the outputs produced "per unit" of input is maximized" (Banker, 1984). Thus, the idea of mpss is related to average productivities. If a dmU is operating under increasing returns to scale, it can increase the output "per unit of input" by increasing its scale. If decreasing returns are prevailing, it can increase the output "per

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<sup>2</sup> Note that "regulators" do not necessarily have an incentive to reach a social optimum. Hence, regulations can also be a cause of X-inefficiency.

unit of input" by decreasing its scale. It follows that at mpss, a dmu operates under constant returns to scale (see Banker (1984), for more details). This is illustrated in figure 1.

Figure 1 Production possibility set and (in)efficient points of production



$$I = (x_i, X_0, y_i, Y_0); I = M, A, B, C.$$

$$T = \{(X = xX_0, Y = yY_0) | X \geq 0 \text{ can produce } Y \geq 0\}$$

At M average productivity ( $ON/MN$ ) is maximized (i.e. M represents a mpss). Furthermore,  $(dy_M/dx_M)(x_M/y_M) = 1$ ; the dmu at M operates at constant returns to scale. The efficiency of a production possibility A can be evaluated against M by taking the ratio  $h_A = (OD/DA)/(ON/MN) = (y_A/x_A)/(y_M/x_M)$ . This inefficiency measure captures both inefficiency due to technical inefficiency at the given scale  $((y_A/x_A)/(y_B/x_B))$  and inefficiency due to a divergence from mpss  $((y_B/x_B)/(y_M/x_M))$ . Let  $k = y_A/y_M$ . Then  $h_A = k(x_A/x_M) = CD/AC$ ; we can determine the most productive scale size (measured for inputs) as  $x_M = (h_A/k) * x_A$ . In order to determine mpss for e.g. A, we need to know  $h_A$  and  $k$ . These coefficients can be determined using DEA. When the DEA programme has a unique solution, we can apply the methodology of Banker (1984). This methodology is extended by Banker and Thrall (1992) to allow for allow for multiple optimal solutions. See also Appa and Yue (1999) for an analysis of scale efficient targets.

<sup>3</sup> Note that for each input-output mix there is a mpss. An mpss is not necessarily the (an) optimal scale size; this depends on the input and output prices.



### 3 Data Envelopment Analysis

In data envelopment analysis (DEA) one uses a series of linear programming problems to draw a production frontier. The efficiency of each airport (or more general, a dmU) is evaluated against this frontier. Hence the efficiency of an airport is evaluated relative to the performance of other airports. More formally, assume we have  $L$  airports with  $m$  outputs and  $n$  inputs. Charnes et al. (1978) propose the following measure of efficiency, which is the maximum of the ratio of weighted outputs to weighted inputs subject to the condition that for every airport the efficiency measure is smaller than or equal to 1:

$$\begin{aligned} & \max \frac{\sum_{i=1}^m u_i y_{i,0}}{\sum_{j=1}^n v_j x_{j,0}} \\ & \text{s. t. } \frac{\sum_{i=1}^m u_i y_{i,l}}{\sum_{j=1}^n v_j x_{j,l}} \leq 1, \quad l = 1 \dots L \\ & \quad u_i, v_j \geq 0 \end{aligned}$$

(1) Charnes et al. (1978) show

that the above fractional programming program has the following linear programming equivalent:

$$\begin{aligned} & \max \sum_{i=1}^m u_i y_{i,0} \\ & \text{s. t. } \sum_{i=1}^m u_i y_{i,l} - \sum_{j=1}^n v_j x_{j,l} \leq 0, \quad l = 1 \dots L \\ & \quad \sum_{j=1}^n v_j x_{j,0} = 1 \\ & \quad u_i, v_j \geq 0 \end{aligned} \tag{2}$$

To determine the mpss the dual to this problem is used:

$$\begin{aligned} & \min h_0 \\ & \text{s. t. } \sum \lambda_l y_{i,l} = y_{i,0}, \quad i = 1, \dots, m \\ & \quad \sum \lambda_l x_{j,l} = h_0 x_{j,0}, \quad j = 1, \dots, n \\ & \quad \lambda_l, h_0 \geq 0 \end{aligned} \tag{3}$$

Banker (1984) shows that a dm<sub>u</sub> represents a mpss iff  $h_o = 1$ . Moreover, by defining  $k_o = \sum_{l=1}^L \lambda_l$ , the

input-output mix  $\left( \frac{h_o}{k_o} X_o, \frac{1}{k_o} Y_o \right)$  is a production possibility (i.e. is an element of T in figure 1) and

is mpss. If the sum of weights  $k_o > 1$ , local decreasing returns to scale are prevailing; if  $k_o < 1$ , local increasing returns to scale are prevailing.

The efficiency coefficient can be either input-oriented (as in (3)) or output-oriented. If the input oriented coefficient  $h_o < 1$  in (3), it is possible to reduce all inputs (by  $(1-h_o) \times 100\%$ ) keeping the outputs constant. Likewise, if the output coefficient is larger than 1 it is possible to increase the outputs keeping the inputs constant.

#### **4 Determination of efficiency coefficients**

The empirical application of this paper is undertaken in two steps. First, the DEA model is used to determine the efficiency coefficients and mpss. Second, the efficiency coefficients are used as dependent variables in a censored regression model to explain the differences in efficiency (as was done by Gillen and Lall (1997) for US airports).

Data on inputs have been obtained from IATA's (1998) Airport Characteristics / Demand Profiles and from some airports directly. The Airport Characteristics / Demand Profiles does not contain information on the number of employees. Numbers of employees can be obtained from the Airport Council International (ACI) (1999). Both the number of people employed by the airport operator and the total number of employees at the airport are available. The first number of people does not include people working for sub-contracting firms. For example, the number of people employed by the operator of FRA (Flughafen Frankfurt Main AG) in 1997 is 12,500. According to the ACI airport database FRA is the only airport operated by the operator. The British Airport Authority (BAA) had 8,393 employees and operates, amongst others, Heathrow, Gatwick and Stansted (BAA, 1999). The numbers of passengers at these airports in 1997 were 58 million for Heathrow and 40 million for Frankfurt. We may assume that such numerical differences reflect differences in the way workers have been classified in the various airports. Unfortunately, vital information is lacking on e.g. subcontracting, the number of people employed for aircraft handling etc. As an alternative we might use the total number of people employed at the airport, but then we would also include people who have little to do with the "airport business" and we would include too much heterogeneity<sup>4</sup>. Therefore, labor is not included in the analysis. This means that an efficient dm<sub>u</sub> may or may not be labor efficient; but by assuming zero substitutability between labor and other factors of production this should not be a problem.

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<sup>4</sup> For example, before the aircraft manufacturer Fokker was closed in 1995, the employment of its Schiphol manufacturing plant was included in the airport employment figure.

As we only have data on runway characteristics and characteristics of passenger terminals, we use two output measures: air transport movements and passenger movements. Data for the period 1995-1997 were obtained from the British Airport Authority.

Like Gillen and Lall (1997), we analyze terminal output (PAX, the number of passengers) and aircraft movements (ATM, air transport movements) separately. Although the airport can be seen as a multi-product firm and the two outputs are clearly related, the "production technology" for the two outputs is quite different. Estimation results for PAX are given in tables 1 and 2. The inputs used were terminal size (square meters), number of aircraft parking positions at the terminal, number of remote aircraft parking positions, number of check-in desks and number of baggage claims.

*Table 1 Relative Efficiency, APM*

City	Airport	1995	1996	1997
Amsterdam	AMS	0.583	0.639	0.728
Berlin	SXF	0.372	0.355	0.374
Berlin	TXL	0.651	0.660	0.686
Brussels	BRU	0.791	0.838	1.000
Bucharest	OTP	0.207	0.200	0.209
Copenhagen	CPH	0.850	0.926	1.000
Dublin	DUB	0.780	0.881	1.000
Faro	FAO	0.997	0.998	1.000
Frankfurt	FRA	0.815	0.828	0.857
Göteborg	GOT	0.442	0.469	0.496
Hamburg	HAM	0.484	0.485	0.510
Hannover	HAJ	0.473	0.493	0.535
Larnaca	LCA	0.647	0.655	0.659
Leeds/Bradford	LBA	0.466	0.366	0.461
Lisbon	LIS	0.795	0.844	0.877
London	LGW	0.785	0.845	0.940
London	LHR	0.936	0.964	1.000
London	STN	0.347	0.430	0.479
Lyon	LYS	0.367	0.411	0.398
Manchester	MAN	0.645	0.634	0.687
Marseille	MRS	0.873	0.956	0.987
Milan	LIN	0.744	0.869	1.000
Milan	MLP	0.315	0.311	0.325
Munich	MUC	0.570	0.602	0.687
Nürnberg	NUE	0.424	0.419	0.455
Paris	CDG	0.466	0.523	0.584
Paris	ORY	0.798	0.821	0.752
Prague	PRG	0.290	0.339	0.373
Rome	FCO	0.782	0.854	0.927
Stockholm	STO	0.777	0.805	0.866
Stuttgart	STU	0.695	0.870	0.922
Turin	TRN	0.195	0.217	0.259
Vienna	VIE	0.864	0.924	0.990
Zurich	ZRH	0.835	0.884	1.000

*Table 2 Sum of weights  $k_0$ , APM*

Airport	1995	1996	1997	RS <sup>1</sup>
AMS	1.282	1.407	1.600	d
SXF	0.106	0.101	0.107	i
TXL	1.353	1.372	1.425	d
BRU	0.791	0.838	1.000	i
OTP	0.100	0.096	0.100	i
CPH	0.850	0.926	1.000	i
DUB	0.780	0.881	1.000	i
FAO	0.997	0.998	1.000	i
FRA	1.694	1.720	1.780	d
GOT	0.201	0.213	0.225	i
HAM	0.463	0.464	0.488	i
HAJ	0.260	0.271	0.294	i
LCA	0.155	0.156	0.157	i
LBA	0.063	0.073	0.084	i
LIS	0.966	1.026	1.066	i/d
LGW	0.613	0.660	0.734	i
LHR	0.936	0.964	1.000	i
STN	0.220	0.272	0.304	i
LYS	0.254	0.283	0.275	i
MAN	0.947	0.930	1.009	i/d
MRS	0.314	0.332	0.342	i
LIN	0.744	0.869	1.000	i
MLP	0.234	0.231	0.241	i
MUC	0.982	1.037	1.184	i/d
NUE	0.066	0.065	0.071	i
CDG	1.276	1.433	1.600	d
ORY	1.688	1.736	1.589	d
PRG	0.189	0.221	0.243	i
FCO	1.193	1.303	1.414	d
STO	0.801	0.830	0.893	i
STU	0.352	0.440	0.467	i
TRN	0.104	0.116	0.138	i
VIE	0.496	0.531	0.569	i
ZRH	0.835	0.884	1.000	i

<sup>1</sup> returns to scale characterization;

i = increasing, d = decreasing

From table 1 it appears that the relative efficiency measure for most airports increases (slightly) over time. The regional dispersion remains more or less constant over time. There are large differences in efficiency between airports in given years, and even among cities. For example, the efficiency coefficient of London Stansted (STN) is much lower than the coefficient for London Heathrow (LHR). The same observation holds true for Flughafen Berlin-Schönefeld (SXF) and Flughafen Berlin-Tegel (TXL). From table 2 it appears that most airports are operating under local increasing returns to scale. Some airports (BRU, CPH, DUB, FAO, LHR, LIN and ZRH) have been increasing their scale of operation such that they are efficient (and mpss) in 1997 compared to previous years and other airports. Other airports (GOT, HAM, HAJ, LCA, LBA, LGW, STN, LYS, MRS, MUC, MXP, NUE, OTP, PRG, STO, SXF, TRN, VIE) have been increasing their efficiency over time, but are still inefficient (are not yet mpss) compared to other airports. These airports could increase their scale to reach mpss. AMS, TXL, FRA, CDG and ORY are operating under local decreasing returns to scale. *Given* their current input combinations, these airports could decrease their scale to reach mpss. As was explained in section 2, this mpss may not be the optimal scale of operations for an airport; this depends on the prevailing output and input prices. In fact, changing the input mix also changes the mpss, and with it, the sign of the returns to scale may change for the years in which these airports did not yet reach mpss: with a more favorable input mix AMS, TXL, FRA, CDG and ORY could improve their position. As was mentioned in the introduction, DEA only measures inefficiency and does not explain. Clearly, more research is needed to explain the unfavorable positions of AMS, TXL, FRA, CDG and ORY and to investigate whether expansion of these airports is economically justified. LIS, MAN and MUC are operating near the mpss ( $k_0$  is just below 1 or just above 1). The relative inefficiency coefficients appear to be on the low side for airports so operating so close to the mpss. This suggests that at these three airports technical inefficiency dominates scale inefficiency.

The inefficiency ratios for ATM are given in table 3. The inputs used are the total airport area (ha), total length of the runway system, number of aircraft parking positions at the terminal and the number of remote parking positions. It appears that, again, over time relative efficiency increases. It appears there are fewer airports achieving relative efficiency (and mpss) in ATM than there are airports reaching relative efficiency (and mpss) in PAX. The observations on the Berlin and London airports made in table 1 also appear in table 3. From table 4, it appears that most airports are, again, operating under local increasing returns to scale, but apart from CDG, CPH, LGW, LHR, LIN and STU no airport reaches mpss. AMS, BRU, FCO, FRA, MUC, ORY, STO and ZRH are operating under local decreasing returns to scale.

The conclusion so far is that for both outputs, most airports are operating under increasing returns to scale. This indicates that, to improve relative efficiency, most airports could increase their scale of operations to reach mpss, or already have done so. Some airports (AMS, FCO, FRA and ORY) could decrease their scale to achieve the mpss at the current input mix. Finally, BRU, MUC and ZRH operate under local increasing returns to scale when looking at PAX, while they are operating under decreasing returns to scale looking at ATM. The opposite holds true for CDG and TXL.

City	Airport	1995	1996	1997
Amsterdam	AMS	0.616	0.682	0.741
Berlin	SXF	0.155	0.160	0.144
Berlin	TXL	0.469	0.488	0.490
Brussels	BRU	0.607	0.661	0.697
Bucharest	OTP	0.154	0.132	0.146
Copenhagen	CPH	0.837	0.937	1.000
Dublin	DUB	0.355	0.353	0.389
Faro	FAO	0.306	0.290	0.297
Frankfurt	FRA	0.905	0.921	0.932
Göteborg	GOT	0.545	0.548	0.564
Hamburg	HAM	0.535	0.542	0.562
Hannover	HAJ	0.438	0.438	0.564
Larnaca	LCA	0.262	0.259	0.266
Leeds/Bradford	LBA	0.567	0.549	0.580
Lisbon	LIS	0.424	0.484	0.465
London	LGW	0.837	0.920	1.000
London	LHR	0.976	0.995	1.000
London	STN	0.410	0.481	0.523
Lyon	LYS	0.289	0.327	0.361
Manchester	MAN	0.749	0.718	0.746
Marseille	MRS	0.427	0.468	0.491
Milan	LIN	0.802	0.949	1.000
Milan	MXP	0.319	0.285	0.302
Munich	MUC	0.754	0.826	0.957
Nürnberg	NUE	0.473	0.476	0.506
Paris	CDG	0.823	0.912	1.000
Paris	ORY	0.654	0.690	0.666
Prague	PRG	0.323	0.348	0.364
Rome	FCO	0.697	0.788	0.819
Stockholm	STO	0.791	0.835	0.904
Stuttgart	STU	0.727	0.810	1.000
Turin	TRN	0.216	0.239	0.280
Vienna	VIE	0.570	0.614	0.618
Zurich	ZRH	0.851	0.914	0.983

Airport	1995	1996	1997	RS <sup>1</sup>
AMS	1.408	1.558	1.692	d
SXF	0.165	0.170	0.153	i
TXL	0.784	0.816	0.819	i
BRU	1.309	1.425	1.503	d
OTP	0.191	0.164	0.182	i
CPH	0.837	0.937	1.000	i
DUB	0.499	0.497	0.547	i
FAO	0.142	0.134	0.138	i
FRA	2.134	2.170	2.197	d
GOT	0.345	0.346	0.357	d
HAM	0.502	0.508	0.527	i
HAJ	0.301	0.301	0.388	i
LCA	0.192	0.189	0.194	i
LBA	0.189	0.183	0.193	i
LIS	0.408	0.466	0.448	i
LGW	0.837	0.920	1.000	i
LHR	0.976	0.995	1.000	i
STN	0.304	0.356	0.388	i
LYS	0.457	0.516	0.570	i
MAN	0.540	0.518	0.539	i
MRS	0.258	0.283	0.297	i
LIN	0.802	0.949	1.000	i
MXP	0.242	0.216	0.229	i
MUC	1.228	1.344	1.557	d
NUE	0.159	0.159	0.170	i
CDG	0.823	0.912	1.000	i
ORY	1.297	1.367	1.321	d
PRG	0.274	0.295	0.309	i
FCO	1.151	1.301	1.352	d
STO	1.163	1.227	1.329	d
STU	0.727	0.810	1.000	i
TRN	0.152	0.169	0.198	i
VIE	0.884	0.952	0.958	i
ZRH	1.015	1.090	1.173	d

<sup>1</sup> returns to scale characterization;  
i = increasing, d = decreasing

The question arises whether the conjecture that returns to scale are relatively stronger at relatively smaller airports is supported by the analysis. There is one airport (TXL) operating under local decreasing returns to scale which is relatively small, and there are 5 relatively large airports (FRA, CDG, ORY, AMS, FCO) that also operate under decreasing returns to scale that do not fit this pattern. Given the different patterns from these 6 airports, we feel the correlation coefficient between APM and  $k_o$  reported in table 2 is sufficiently high (0.718) to provide some support for the conjecture that low values of  $k_o$  (high returns to scale) coincide with relatively high values of APM. The same

holds true for ATM, where the correlation coefficient (between ATM and  $k_0$  reported in table 4) is even higher (0.863).

Using the efficiency coefficients and sums of weights reported in tables 1-4, we can determine the mpss for these airports as indicated in sections 2 and 3. As already mentioned, these are the mpss *given* the current input proportions; it might be better for an airport to adjust the input ratio rather than to change all inputs proportionally. Without data on input prices, however, it is difficult to say anything about the “optimal mpss”. Moreover, given the indivisibilities, interpreting the mpss may be difficult. This becomes clear in table 6, appendix 2, where, for example, LBA should construct no less than 6 runways with an average length of 1675 meters length to reach the mpss. With an average length of 2930 meters the number reduces to 3, which is more in line with the APM at the mpss.

From table 5 it appears that a number of airports (GOT, HAJ, HAM, LBA, LCA, LGW, LYS, MRS, MXP, NUE, OTP, PRG, STN, STU, SXF, TRN and VIE) have a large growth potential compared to the other airports at the current input mix. AMS, CDG, ORY and TXL on the other hand have no growth potential at the current input mix.

Note that while TXL could decrease its size, the other Berlin airport, SXF, could increase its scale. A similar observation is made for the London airports, where LGW and STN could increase their scale of operations and LHR should remain constant.

Changing the input mix changes the results; for example reducing the total length of the runway system and the number of parking positions at AMS (so that they are proportional to LHR) but keeping the airport area constant renders AMS efficient in 1997 and changes the sign of the returns to scale<sup>5</sup>. From an economic perspective, this may be a better position for AMS than the mpss reported in table 6. The mpss reported in tables 5 and 6 are technically efficient, but not necessarily cost efficient. To determine the “true” optimal scale of operations, also cost data are needed. These are not have available.

A final observation made on the basis of tables 5 and 6 is that the number of aircraft parking positions at the PAX mpss is, on average, larger than the number of aircraft parking positions at the ATM mpss; a larger number of parking positions is needed to handle passengers than is needed to accommodate arriving and departing aircraft. Second, more inputs may be needed. For example, in this model, the airport which has e.g. the smallest terminal size compared to the number of passengers is (can be) the most efficient. However, a larger terminal allows for more amenities at the airport, which may be needed to attract passengers.

## 5 Stochastic Frontier Analysis

In this section, the results of the previous section will be compared to the results of a stochastic frontier analysis. Consider the following stochastic production frontier:

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<sup>5</sup> AMS area: 2200, runway length: 5248, terminal positions: 72, remote positions: 37.

$$y_{j,t} = x_{j,t}' \beta + E_{j,t}$$

$$E_{j,t} = V_{j,t} - U_j$$

(5)

where  $y_{j,t}$  is the output of airport  $j$  in period  $t$  and  $x_{j,t}$  are the inputs of airport  $j$  in period  $t$ . Both  $y$  and  $x$  can be defined in terms of the original units of productions or in logarithms.  $U_j \sim N(0, \sigma_u^2)$  and IID and is also independent of  $V_{j,t}$ , which is distributed according to half normal distribution with variance  $\sigma_v^2$ .  $U_j$  is the (stochastic) deviation from the production frontier; for  $U_j > 0$  airport  $j$  does not reach the (efficient) frontier. The technical efficiency of airport  $j$  is<sup>7</sup> (see also Battese and Coelli (1988)):

$$h_j^f = \frac{E(y_{j,t} | U_j, x_{j,t})}{E(y_{j,t} | U_j = 0, x_{j,t})}$$

(6)

where the superscript denotes that the efficiency coefficient is obtained from a frontier model. If equation (5) is specified in logs, then  $h_j^f = \exp(V_j)$ .

Note that the stochastic frontier model in equation (5) can be extended to explain the inefficiencies  $U_j$ . The frontier model and the inefficiency model  $U_j = U_j(Z_j)$  are estimated simultaneously. Unfortunately, we do not have the necessary variables  $Z_j$  to explain the inefficiencies.

Both the models explaining *ATM* and *APM* were specified in logs. Not all variables used in the DEA could be used to estimate a stochastic production frontier<sup>8</sup>. For the model explaining *APM*, The explanatory variables included are, next to a constant, the number of baggage claim units *claims*, the number of parking positions at the terminal (*pos*) and the number of remote parking positions *pos*. The estimates are (standard error between parentheses):

OLS:

$$\ln(APM) = 5.907 + 0.826 \cdot \ln(claims) + 0.261 \cdot \ln(pos) + 0.165 \cdot \ln(rem)$$

(0.297) (0.097) (0.060) (0.105)

ML:

$$\ln(APM) = 6.471 + 0.771 \cdot \ln(claims) + 0.253 \cdot \ln(pos) + 0.201 \cdot \ln(rem)$$

(0.384) (0.099) (0.058) (0.110)

$$\text{Log(likelihood)} = -76.47 \quad \gamma = \sigma_u^2 / \sigma_v^2 = 2.17 (1.15)$$

The null hypothesis  $\gamma = 0$  is rejected at the 90% confidence level. Note that, as  $\gamma$  is larger than 2, the variance of  $U_j$  is large compared to the variance of  $V_{j,t}$ , indicating there is a substantial inefficiency effect. The variables explaining *ATM* are: *runways* is the number of runways, *pos* is the number of aircraft parking positions at the terminal and *rem* is the number of remote parking positions.

<sup>6</sup> There are other distributions for  $V$  possible, see e.g. Battese and Coelli (1988).

<sup>7</sup> Note that, again, a technically efficient airport may operate cost inefficiently.

OLS:

$$ATM = 1.777 + 0.501 \cdot \ln(runways) + 0.343 \cdot \ln(pos) + 0.435 \cdot \ln(rem) \\ (0.311) \quad (0.140) \quad (0.059) \quad (0.103)$$

ML:

$$ATM = 2.426 + 0.404 \cdot \ln(runways) + 0.314 \cdot \ln(pos) + 0.472 \cdot \ln(rem) \\ (0.479) \quad (0.134) \quad (0.048) \quad (0.115)$$

$$Log(likelihood) = -82.10 \quad \gamma = \sigma_u^2 / \sigma_v^2 = 2.60 \quad (0.08)$$

Again, the null hypothesis  $\gamma = 0$  is rejected at the 90% confidence level and there is a substantial inefficiency effect.

It is noted that a yearly dummy  $D$  may be necessary (as we have pooled time series - cross section data), but taking this into account in the estimations does not change the results. Moreover, the estimation results are not really robust. Including additional variables may necessitate a different specification of the production function. Also, the null hypothesis  $\gamma = 0$  is rejected at the 90% confidence level, but is not rejected at 95% confidence.

The efficiency coefficients  $h_j^f$  are reported in appendix 3. Despite the fact that there is somewhat less temporal and regional dispersion of the efficiency coefficients using stochastic frontier models than they are using DEA (the error term in equation (5) consists of the "inefficiency"  $U_j$  and the "noise"  $V_{j,n}$  which is "filtered out"<sup>8</sup>), the stochastic efficiency frontier model seems to be able to reproduce the DEA results quite reasonably. Notable exceptions are OTP and MXP which perform much better when looking at the stochastic frontier model, and TXL, MXP and ORY which perform much worse under the stochastic frontier model.

Although the estimations do not seem to be very robust, the stochastic frontier model quite reasonably reproduces the DEA results. Future research, using more flexible specifications, should verify this result.

## Conclusion

In this paper efficiency indices and most productive scale sizes were determined for European airports. Most airports seem to be operating under increasing returns to scale. Large differences in relative efficiency exist, and also large deviations from the mpss are found. It should be kept in mind that the mpss are determined given the current input-mix. A change in the input mix may lead to different outcomes.

<sup>8</sup> A less restrictive assumption on the distribution of  $U_j$  would be that  $U_j \sim N(\mu, \sigma_u^2)$ , truncated at 0. Including all variables, the null hypotheses  $\mu = 0$  and  $\sigma_u^2$  are, however, not rejected;  $U_j$  cannot be distinguished from 0.

<sup>9</sup> It is noted that care should be taken comparing the results of a non-parametric and a parametric approach.



Some airports, like AMS, are operating under local decreasing returns to scale. As a result, the mpss lies well below the current scale of operations. This indicates that a reduction in the scale of operations (both in inputs and outputs) would be wise, but a change in the input mix could be more advisable. For example, using the input mix of LHR, but then proportionally to the demand at AMS (see footnote 8), results in a mpss with a higher output than the mpss reported in table 6 (actually, the mpss for ATM is the same as realized output for 1997). Thus, from this analysis of production efficiency, we can conclude that i) AMS has probably not an optimal input mix (even at the mpss reported in table 6) and ii) in any case, the planned construction of a fifth runway is not a good idea, from a pure economic point of view. But, as already mentioned in the introduction, this analysis was primarily focused on the measurement of inefficiency. In the case of AMS, the inefficiency is, for a large part, caused by regulations. This becomes clear from figure 2. The politically instigated noise contours are "chosen" such that the overlap with population centers is minimized. The expected growth in the number of air transport movements (ATM) will increase the noise (and safety) problem. Given the regulation, the expected growth apparently cannot be accommodated at the existing runway system. Hence a fifth runway is planned. From a pure economic point of view, this is, as already said, not the optimal solution.

The stochastic frontier analysis seems to produce reasonable efficiency coefficients and might be considered more flexible than DEA as it includes a "noise" term; the inefficiency is the distance to the frontier *plus* a random error term rather than to the (different) frontier itself as in DEA. The use of a more flexible functional form of the production function may however be necessary if this method is used to measure and explain inefficiency.

The research agenda that follows from this paper is the following. First and foremost, more attention has to be paid to the "explaining" of inefficiency, either using a stochastic frontier model or DEA output. Second, as the mpss is not necessarily the optimal scale of an airport, an (empirical) analysis of airport cost functions should shed more light on the "true" optimal scale of an airport; this is the mpss at the cost minimizing input mix.

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### ***Appendix 1 Airports used in the Analysis***

AMS	Amsterdam Airport Schiphol	LIS	Lisbon International
BRU	Brussels National	LYS	Aéroport de Lyon-Satolas
CDG	Charles de Gaulle	MRS	Aéroport International Marseille-Provence
CPH	Copenhagen International Airport	MUC	Flughafen München
DUB	Dublin	NUE	Flughafen Nürnberg
FAO	Faro	ORY	Orly
FCO	Leonardo da Vinci	OTP	Otopeni International
FRA	Frankfurt Main International	PRG	Ruzyně
GOT	Göteborg-Landvetter Airport	STN	London Stansted
HAJ	Hannover	STU	Flughafen Stuttgart
HAM	Hamburg International	SXF	Flughafen Berlin-Schönefeld
LBA	Leeds-Bradford International Airport	TRN	Citta' Di Torino
LCA	Larnaca	TXL	Flughafen Berlin-Tegel
LGW	London Gatwick	VIE	Vienna International
LHR	London Heathrow	ZRH	Zürich International

## Appendix 2 MPSS and Data, 1997

Table 5 MPSS, PAX

	PAX	terminal size (m <sup>2</sup> )	aircraft parking positions		check-in desks	baggage claims
			positions	remote		
AMS	19382	168197	30	27	151	9
BRU	15935	125000	32	66	143	5
CDG	21933	161292	23	34	157	9
CPH	16837	97000	49	14	84	7
DUB	10235	37889	50	37	99	5
FAO	3664	4400	6	13	31	5
FCO	17684	114753	16	31	119	8
FRA	22542	338776	24	35	194	16
GOT	15097	97030	18	42	90	7
HAJ	15922	72818	22	33	95	22
HAM	17530	69530	67	37	101	10
LBA	14786	208500	7	119	194	22
LCA	23345	87976	121	121	168	13
LGW	36508	184806	67	38	287	20
LHR	57808	211400	104	53	482	30
LIN	14395	67400	5	31	93	6
LIS	6223	19423	6	24	77	7
LYS	17530	69541	33	72	101	14
MAN	15574	49932	40	22	140	11
MRS	16280	235757	81	45	178	6
MUC	14891	109755	14	30	91	7
MXP	14609	70971	7	31	93	7
NUE	33981	119050	90	38	269	19
OTP	14674	83235	10	85	92	8
ORY	15748	175757	17	27	98	8
PRG	16755	115726	48	25	84	9
STN	17678	77348	47	33	133	8
STO	16742	123382	97	124	90	7
STU	14446	84750	6	69	93	12
SXF	17537	69234	81	109	102	11
TRN	17232	81343	58	49	94	9
TXL	6049	13062	25	41	44	8
VIE	16867	55694	35	85	146	10
ZRH	17871	56000	24	30	110	12

Table 6 MPSS, ATM

	ATM	Airport		Runway Length (m)	aircraft parking positions	
		Area (ha)	Runways		terminal	remote
AMS	207	963	2	5890	28	26
BRU	169	577	1	4559	15	31
CDG	396	3109	2	7800	63	93
CPH	284	1240	3	8665	49	14
DUB	222	768	2	4275	36	26
FAO	186	1084	2	5367	13	28
FCO	182	969	2	6722	15	28
FRA	177	806	1	5090	21	31
GOT	170	1186	2	5219	13	30
HAJ	199	896	4	10067	17	26
HAM	241	601	2	7369	68	37
LBA	135	429	6	10050	3	48
LCA	182	397	1	3698	40	40
LGW	229	759	1	3098	52	30
LHR	429	1200	2	7560	104	53
LIN	165	360	2	2440	5	31
LIS	171	522	2	6445	7	30
LYS	165	696	1	4222	15	32
MAN	276	831	1	4224	82	44
MRS	280	991	3	9744	48	26
MUC	164	921	1	4914	15	32
MXP	170	1611	3	9946	7	30
NUE	264	1075	3	8059	42	18
OTP	180	778	2	4728	18	29
ORY	150	617	2	5627	4	33
PRG	250	1062	4	10694	36	19
STN	218	1293	1	4113	40	28
STO	194	435	1	3946	68	87
STU	135	240	1	3345	3	35
SXF	200	598	2	5363	22	29
TRN	190	425	1	4680	44	37
TXL	145	278	1	3256	30	51
VIE	163	645	1	4582	13	32
ZRH	206	677	3	7966	20	25

Table 7 Data, 1997

	Airport			Runways	Runway Length	Terminal Size	Aircraft parking positions		Check-in desks	Baggage claims
	PAX	ATM	Area				terminal	remote		
AMS	31021	349.5	2200	4	13450	370000	65	60	333	19
BRU	15935	254.7	1245	3	9833	125000	32	66	143	5
CDG	35103	395.5	3109	2	7800	442200	63	93	430	26
CPH	16837	283.6	1240	3	8665	97000	49	14	84	7
DUB	10235	121.3	1080	3	6010	37889	50	37	99	5
FAO	3664	25.6	503	1	2490	4400	6	13	31	5
FCO	25001	245.7	1600	3	11095	175000	25	47	182	12
FRA	40128	389.6	1900	3	12000	704000	49	73	403	34
GOT	3394	60.8	750	1	3300	44000	8	19	41	3
HAJ	4676	77.1	616	3	6920	40000	12	18	52	12
HAM	8546	127.1	564	2	6910	66500	64	35	97	10
LBA	1247.7	26.1	143	2	3350	28000	1	16	26	3
LCA	3673	35.3	290	1	2700	21000	29	29	40	3
LGW	26795	229.3	759	1	3098	144361	52	30	224	16
LHR	57808	429.2	1200	2	7560	211400	104	53	482	30
LIN	14395	165.3	360	2	2440	67400	5	31	93	6
LIS	6631	76.8	503	2	6205	23598	7	29	93	8
LYS	4819	94.1	1100	2	6670	48000	23	50	70	10
MAN	15714	148.5	600	1	3048	73300	59	32	206	16
MRS	5574	83.3	600	2	5900	84750	29	16	64	2
MUC	17626	256	1500	2	8000	189000	24	52	157	12
MXP	3523	38.8	1220	2	7530	52700	5	23	69	5
NUE	2418	44.8	360	1	2700	18600	14	6	42	3
OTP	1470.7	27.3	768	2	7000	40000	5	41	44	4
ORY	25023	237.1	1541	3	9370	371500	36	58	207	16
PRG	4078	77.3	902	3	9085	75500	31	16	55	6
STN	5366.6	84.4	958	1	3048	49000	30	21	84	5
STO	14951	257.4	640	2	5800	127205	100	128	93	7
STU	6745	134.9	240	1	3345	42918	3	35	47	6
SXF	1870	30.7	636	2	5700	19760	23	31	29	3
TRN	2377	37.6	300	1	3300	43300	31	26	50	5
TXL	8622	119.1	465	2	5447	27150	51	86	92	17
VIE	9597	155.9	1000	2	7100	32000	20	49	84	6
ZRH	17871	241.5	807	3	9500	56000	24	30	110	12

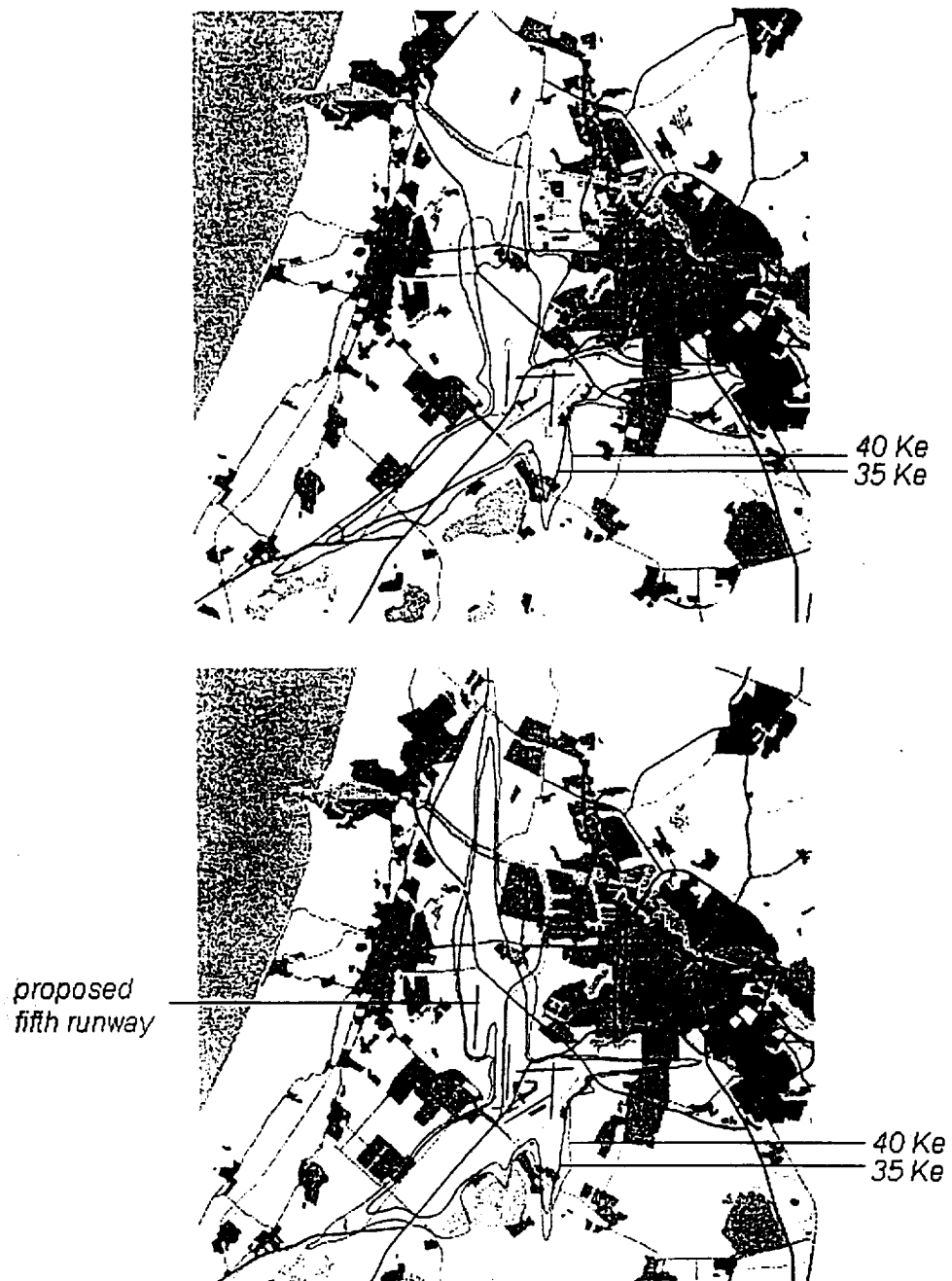
### Appendix 3 Frontier efficiency measures

Table 8, efficiency coefficients from frontier analysis

		ATM			APM		
		95	96	97	95	96	97
Amsterdam	AMS	0.600	0.643	0.677	0.633	0.668	0.714
Berlin	SXF	0.206	0.211	0.193	0.350	0.337	0.351
Berlin	TXL	0.320	0.332	0.333	0.281	0.285	0.294
Brussels	BRU	0.610	0.646	0.668	0.797	0.810	0.843
Bucharest	OTP	0.641	0.663	0.648	0.756	0.764	0.738
Copenhagen	CPH	0.830	0.851	0.861	0.813	0.830	0.843
Dublin	DUB	0.384	0.383	0.416	0.655	0.700	0.741
Faro	FAO	0.446	0.425	0.434	0.641	0.642	0.643
Frankfurt	FRA	0.747	0.753	0.757	0.638	0.643	0.657
Göteborg	GOT	0.668	0.670	0.682	0.663	0.685	0.705
Hamburg	HAM	0.458	0.462	0.477	0.433	0.433	0.451
Hannover	HAJ	0.447	0.447	0.551	0.351	0.363	0.388
Larnaca	LCA	0.265	0.263	0.269	0.570	0.575	0.577
Leeds/Bradford	LBA	0.506	0.493	0.516	0.421	0.467	0.533
Lisbon	LIS	0.555	0.613	0.596	0.616	0.640	0.654
London	LGW	0.796	0.819	0.836	0.715	0.739	0.770
London	LHR	0.799	0.804	0.805	0.749	0.758	0.768
London	STN	0.521	0.589	0.626	0.467	0.550	0.594
Lyon	LYS	0.348	0.387	0.421	0.308	0.337	0.329
Manchester	MAN	0.691	0.674	0.689	0.537	0.529	0.562
Marseille	MRS	0.500	0.539	0.559	0.821	0.832	0.838
Milan	LIN	0.813	0.847	0.856	0.856	0.876	0.891
Milan	MXP	0.426	0.386	0.407	0.587	0.582	0.600
Munich	MUC	0.720	0.751	0.794	0.673	0.693	0.737
Nürnberg	NUE	0.680	0.682	0.706	0.582	0.577	0.611
Paris	CDG	0.682	0.721	0.752	0.551	0.598	0.642
Paris	ORY	0.247	0.217	0.236	0.313	0.303	0.315
Prague	PRG	0.408	0.434	0.452	0.366	0.415	0.449
Rome	FCO	0.684	0.730	0.743	0.790	0.810	0.827
Stockholm	STO	0.409	0.429	0.459	0.589	0.604	0.633
Stuttgart	STU	0.831	0.851	0.881	0.703	0.772	0.787
Turin	TRN	0.232	0.254	0.292	0.236	0.259	0.299
Vienna	VIE	0.618	0.649	0.652	0.686	0.709	0.732
Zurich	ZRH	0.763	0.784	0.803	0.719	0.737	0.773

Figure 2

Noise contours at Schiphol<sup>1,2</sup>



1) source: PMMS (1996)

2) Ke means "Kosten eenheid", a function of the number of decibels. As a rule,  $(Ke-10)\%$  of the population living in an area is seriously affected by aircraft noise.



# A Critical Examination of an Airport Noise Mitigation Scheme and an Aircraft Noise Charge: The Case of Capacity Expansion and Externalities at Sydney (Kingsford Smith) Airport

Giovanni Nero and John A. Black \*  
School of Civil and Environmental Engineering,  
University of New South Wales,  
Sydney, 2052, Australia.

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## Abstract

In the wake of the Australian airline liberalization in 1990 and its forecasted impact on air traffic, capacity has been expanded at Sydney (Kingsford Smith) Airport [Sydney KSA] – Australia's busiest commercial airport – with the construction of the third runway in 1994. Coinciding with the approval for this capacity expansion, the Commonwealth Government amended the Federal Airports Corporation (FAC) Act to direct the FAC to carry out activities which protect the environment from the effects of aircraft operations, with the cost to be borne by the airline industry according to the 'Polluter Pays Principle'. Noise management plans were part of the conditions for developmental approval for a third runway. To this end, since 1995, Sydney KSA imposes a noise levy designed to generate sufficient revenues to fund a noise mitigation scheme. Although the issues of aircraft noise, in particular its impact on property values and land use planning around the airport, have been extensively addressed in the literature, no one has empirically examined the implications of new environmental policies in conjunction with airline liberalisation and change in airport infrastructure. Principles and policy analyses are discussed in this paper. By focusing on the specifics of Sydney KSA, broader policy issues likely to be relevant for other major airports around the world are discussed.

**Key words:** Airline Liberalisation, Airport Capacity, Environmental Impact, Aircraft Noise, Noise Levy.

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\*gio.nero@workmail.com and j.black@unsw.edu.au, respectively. PRELIMINARY DRAFT. All comments welcome. Dr Nero thanks the Swiss National Science Foundation for financial support (Grant no. 8210-50417).

in Section 5, in which we also examine the properties of this charge against OECD (1991) criteria and set out potential limitations of the NLC formula used at Sydney KSA.

The impacts of the NLC on aircraft operations and on its customers are examined in Section 6. Specifically, we take a range of demand elasticities and estimate the effects of differing levels of NLC. Aircraft noise has profound social impacts, especially on those living near the airport, and runway usage and flight paths determine the spatial distribution of noise. Section 7 examines these distribution consequences - both for the parallel runway operations and for the current policy of 'sharing aircraft noise' encapsulated in AirServices Australia Long Term Operating Plan (LTOP) of 1996. Finally, in Section 8 our conclusions are set out.

## 2 Deregulation and Traffic Growth at Sydney KSA

A growth in air traffic volume can be induced by a combination of several forces: demand factors (e.g. increase of GDP), supply factors (e.g. a change in the industry structure following a merger), and institutional factors (e.g. policy changes bringing deregulation or liberalization). Environmental constraints are likely to arise at any airport experiencing growth in traffic volume. In a related paper Nero and Black (1998) have argued that the problem of environmental externalities is exacerbated by hub development and that, to some extent, hubbing contributes to a spatial redistribution of externalities. Since the Australian airline industry has experienced major changes in competition policy this last decade, a somewhat detailed structural analysis of the impact of deregulation on Sydney SKA is needed at this point<sup>1</sup>. To this end, Table 1 presents a brief summary of the major historical events that have shaped the Australian airline industry, and that have influenced, to some extent, Sydney KSA development. In terms of competition policy the major event is the deregulation of the domestic market in November 1990.

Insert Table 1 here.

Within the context of the above events, the following analysis shows the extent to which Sydney KSA has retained its role and importance as the primary Australian domestic and international gateway. Table 2 and Table 3 show that Sydney KSA is by far the largest airport in Australia. Throughout the 90s Sydney KSA passengers market share has been fairly stable, although its share of international aircraft movements has been recently eroded by Brisbane Airport.

Insert Table 2 and Table 3 here.

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<sup>1</sup>For a partial assessment of Australian airline deregulation see BTCE, 1995a, and more recently Forsyth, 1998b.

same general comments apply to the more disaggregated data of the second and third row of Table 5. It is however important to notice that the second group (Sydney Only) has significantly and consistently larger growth rates (except for load factors) than the other group. This result tends to suggest that, since deregulation of the domestic airline industry, the more than proportional increase in traffic on the Sydney routes has been accommodated by a more than proportional increase in flight frequency and a more than proportional increase in aircraft size.

Table 6 and Table 7 display the evolution of aircraft movements and passengers at Sydney KSA according to the different types of markets, respectively. This enables us to more accurately determine the factors that have driven the sustained growth in aircraft movements at Sydney KSA during the last decade. Impressive growth rates are achieved for each segment of the market in terms of both passengers and, although smaller, aircraft movements. Table 6 and Table 7 show that regional traffic has experienced a phenomenal growth during the last decade at Sydney KSA. In fact, Sydney KSA has consolidated its position as the largest centre for regional traffic in Australia, with its share of total Australian regional traffic increasing from 11.9% to 20.5% in terms of passengers, and from 8.6% to 14.0% in terms of aircraft movements during the 1989-1997 period. This result suggests that Sydney KSA attracted proportionally more regional traffic than other airports during the 1989-1997 period. Deregulation has brought new regional airline operators (some of the largest entrants are in fact subsidiaries of incumbents Qantas Airways and Ansett Airlines) and these operators have been clearly attracted by the larger catchment area of the Sydney basin, and by its ability to feed the domestic and international routes.

Insert Table 6 and Table 7 here.

In summary, the fundamental changes in competition policy (deregulation) have stimulated demand through a mix of lower fares and higher frequency (see also, BTCE, 1995a and Forsyth, 1998b). Major Australian airlines have also increased the size of their fleet in order to meet this demand. Preliminary empirical evidence suggests that there has been little scope for major Australian airlines to reshape their networks in order to gain economic efficiency (see also Jatmika, 1999). Within this context, Sydney KSA has been able to strengthen its position as the primary national and international gateway, and to continue to experience impressive growth rates in aircraft movements and traffic, without however becoming a large US-style hub airport<sup>5</sup>. Undoubtedly, this will have an impact on both airport capacity and aircraft noise, the primary concerns of this paper. In fact, Sydney KSA has the worst record in terms of the magnitude of aircraft noise on surrounding communities<sup>6</sup> around major Australian airports. This is, of course, not surprising given Sydney KSA's growth and its proximity (location) to the center business district. Table 8 provides an estimation of the population (private

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<sup>5</sup> Nevertheless, there is evidence of some hubbing activity at Sydney KSA (see also Section 5.2).

<sup>6</sup> This is assessed using the Australian Noise Exposure Index (20,25,30,35, and 40).

clear tradeoff between capacity expansion and negative externalities. Although the above figures suggest that, in this particular case, the cost of environmental externalities (based on present practise of quantifying them) is small compared to the projected economic benefits, transport decision making must be cognisant of principles of sustainability where economic, social and environmental factors and the mitigation of adverse impacts are included in the evaluation framework.

## 4 Measures to Address the Externality Problem at Sydney KSA

In order to address the externality problem at Sydney KSA, an Environmental Impact Statement (EIS) was commissioned by the FAC, which subsequently satisfied Federal Commonwealth environmental legislation. Construction of the third runway was approved subject to recommendations aimed at finding ways to reduce the unhealthy and socially disruptive impacts upon the residents and environment of Sydney. These recommendations have been detailed in the Draft Noise Management Plan and the Draft Air Quality Management Plan (Mitchell McCotter, 1994a, 1994b, 1994c, 1994d). Following the recommendation of the Draft Noise Management Plan, the Australian Federal Government adopted a Final Noise Management Plan (1996), not released to the public, which combines: (a) a list of measures to alleviate the noise problem in line with a traditional direct regulatory approach ('command-and-control') and, (b) the formulation of a noise levy on aircraft in order to raise the money for these measures. In contrast to the direct approach, the second type of instrument is more market-oriented. We discuss both approaches in turn.

### 4.1 Direct Regulatory Approach ('Command-and-Control')

The 'command-and-control' approach involves the setting of technical and environmental standards enforced via legislation without the aid of market-based incentives. This has been so far the traditional and preferred approach adopted by airports and regulators when dealing with noise-related issues. For example, prior to the construction of the third runway at Sydney KSA, the Australian Government implemented the gradual phasing-out of Chapter 2 aircraft to be completed in a seven year period from January 1995 to April 2002. In addition to this mandatory measure towards noise reduction, the Australian Government determined new measures specific to the Sydney KSA capacity expansion and its noise-related problem. The principal new resolutions chosen to be a part of the noise mitigation policy can be described as operational measures and administrative measures. The operational measures include:

- specific noise abatement procedures for aircraft operations and airport ground operations (e.g., preferential runway use system, preferential flight track use); operating restrictions and slot allocations (essentially, a limit on both the number and type of aircraft for domestic and international operations during curfew time {11pm-6am});

Following the recommendation of the Draft Noise Management Plan (Mitchell McCotter, 1994a, 1994b), the Federal Commonwealth Government has adopted user charges following the Polluter Pays Principle on the aviation industry<sup>8</sup>. While the main aim of a standard Pigouvian tax is economic efficiency (i.e., optimal levels of production and consumption), the main objective of the Polluter Pays Principle, as formulated by OECD in 1972, is equity: "the polluter should bear the cost of measures to reduce pollution decided upon by public authorities to ensure that the environment is an acceptable state" (quoted in Wallart, 1999). Since the empirical estimation of the environmental and financial impact due to airlines' operations is a far from exact procedure, most governments, aviation and/or airport authorities rely on an *ad hoc* formula to apply the Polluter Pays Principle<sup>9</sup>. In general, regulatory authorities follow the principles recommended by International Civil Aviation Organization (ICAO) when setting environmental (mostly noise-related) levies. ICAO policy on environmental levies recommends that any environmental levies on air transport which States may introduce should be in the form of charges rather than taxes, and that the funds collected should be exclusively applied towards mitigating the environmental impacts associated with air transport activity ("no fiscal aims behind the charges") (ICAO, 1998a). More specifically, with respect to noise-related charges, ICAO recommends that the following principles should be applied (ICAO, Appendix A, 1998b):

- Noise-related charges should be levied only at airports experiencing noise problems and should be designed to recover no more than the costs applied to their alleviation or prevention (charges should relate to costs).
- Any noise-related charges should be associated with the landing fee, possibly by means of surcharges or rebates, and should take into account the noise certification provisions of Annex 16 (ICAO, 1993) in respect of aircraft noise levels.
- Noise-related charges should be non-discriminatory between users and not be established at such levels as to be prohibitively high for the operation of certain aircraft. In addition, the charges should not discriminate against air transport compared with other modes of transport.

Moreover, industry trade associations like International Air Transport Association (IATA), Association of European Airlines (AEA), and Airport Council International

<sup>8</sup>Legislation to implement the noise charge was introduced early in 1995, and became effective July 1, 1995 (Aircraft Noise Levy Act 1995). It is important to stress that under the Aircraft Noise Levy Collection Act 1995, Sydney KSA is the only 'qualifying airport' in Australia. Two conditions are required to be a qualifying airport at a particular time: (a) at the time there is a public building within a 25-unit contour, or a residence within a 30-unit contour shown on an ANEF previously prepared for the area around the airport for a date after that time; and (b) the Commonwealth is funding at that time, or has funded before that time, a noise amelioration program for the airport. Note that once an airport has become a qualifying airport, it remains a qualifying airport even if it no longer meets condition (a) (see Art. 6.5).

<sup>9</sup>User charges are usually set lower than pure Pigouvian taxes, resulting in a higher level of externality, all else equal. Wallart (1999) shows that a suboptimal user charge level can result in the optimal pollution level, provided that its revenue is used for abatement spending, and that the user charge level is set adequately.

1998, the LUR was set at Aus\$ 165.18, i.e. a nominal increase of 6.6% throughout the 95-98 period<sup>11</sup> (see Table 11).

Insert Table 11 here.

Table 12 clearly shows that noisier aircraft pay more, all else being equal. The difference in the NLC between the B-737-200 and the B-737-400 is quite striking. The levy for the B-737 Chapter 2 version is three times larger than the levy for the Chapter 3 version. There are also important differences on a *per passenger* basis and, to a lesser extent, depending on the seating configuration of aircraft. According to Table 12, the difference between a Chapter 2 aircraft and a Chapter 3 aircraft in the charge *per passenger* is larger for smaller airplanes. Indeed, the charge *per passenger* for a B-747 or a DC-10 does not vary noticeably according to its Chapter certification. However, for aircraft in the range of 65-165 passengers, the charge *per passenger* is significantly larger for Chapter 2 aircraft. For example, for a similar capacity range, a F-28 has a charge of around Aus\$ 8.50 *per passenger*, in comparison to around Aus\$ 2.00 for a BA-146. Given this result, one could argue that there is a strong economic incentive for airlines to phase-out smaller Chapter 2 aircraft first and/or to operate those aircraft in other city-pairs. We will come back to some of these issues in Section 6.

Insert Table 12 here.

## 5.1 Properties and Advantages of the NLC Scheme

According to OECD (1991) guidelines for the application of economic incentive instruments, there are a number of general criteria against which the various economic instruments can be normally evaluated. These criteria are: the *environmental effectiveness* principle; the *equity* principle; the *(static and dynamic) economic efficiency* principle; the *administrative cost-effectiveness* principle; and the *acceptability* principle. We examine them critically with respects to the NLC at Sydney KSA. In practice, these principles often conflict with each other, forcing the adoption of compromises and/or of innovative solutions.

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Table 12 for details on the noise metrics). The total number of NU corresponds to  $(10,000 \cdot 6.44) \div (90,000 \cdot 1.96) = 240,800$ . If the total funds to be generated for a particular year is Aus\$ 40 million, the LUR (i.e. the \$ value of one noise unit) would be equal to Aus\$ 166.10, so that a Boeing 737-200 would pay a NLC equal to Aus\$ 1070.00, while a Boeing 737-400 aircraft would pay a NLC equal to Aus\$ 326.00 *per landing*.

<sup>11</sup>The Aircraft Noise Levy Act 1995 provides that, for the financial year ending June 1996, the LUR should be less than Aus\$ 180.00, with a maximal increase of 10% for the following year.

the *equity* principle seems observed since the NLC does not confer a disproportionate burden on the least well-off aircraft operators and/or aircraft users (passengers) (see Table 12). Whether the current NLC is (sufficiently) *efficient* in providing continuous incentives for noise nuisance reductions is rather difficult to answer given, *inter alia* financial, technological and operational constraints (see also Section 6 and Section 7).

## 5.2 Potential Limitations of the NLC Scheme

We see however several limitations with the current NLC scheme:

1. The most significant issue is that the level of the noise levy is set by the sum needed to fund compensation and not by the marginal cost that noise nuisances impose on society<sup>14</sup>. However, from an economic efficiency point of view, a noise levy should reflect the true marginal costs created by the externality, as well as the marginal abatement costs (which depend on the technology available for, e.g., engine hushk-its, windows insulation, etc.). Because the sum needed to fund compensation is set to vary each year (and eventually it is set to tend towards zero after a period of 10 years), while the true marginal costs are likely to be more steady, the divergence from marginal cost pricing could be substantial in the medium/long run.
2. The 265 (EPNdB) ANL threshold level is arbitrary, and does not imply that only aircraft with an ANL greater than 265 induce noise environmental damages. Noise levy exempt aircraft like the MD-90-30 (with an ANL equivalent to 260), the Saab 2000, the Fokker 50, and some versions of the BAe146, are not exactly 'silent' aircraft, and therefore also induce negative externalities. Similarly, the NLC does not apply to propeller aircraft or to helicopters. In designing the formula there was a strong desire to "achieve a degree of comparability between the total funds raised from international and domestic/commuter operations" (FAC, p.9.6, 1990). Indeed, because domestic operations at Sydney KSA strongly outweigh international operations<sup>15</sup>, and because domestic and regional operations use smaller aircraft than international operations, there was a concern that the burden of the noise levy would proportionally be more important on domestic markets, unless small jet aircraft would be less heavily taxed, or completely exempt. Clearly, from an economic efficiency point of view it is fair that quieter aircraft should be taxed less. Whether it is desirable from an equity point of view that larger noisier aircraft are heavily taxed (surcharge) while the smaller quieter aircraft are noise levy exempt (some sort of rebate) is debatable. One can argue that this scheme provides some incentive for aircraft substitution. However, we believe that this substitution is rather limited, because the more noise-efficient aircraft can have very different operational characteristics (i.e. size, range, etc.) than the less noise-efficient aircraft<sup>16</sup>.

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<sup>14</sup>It is therefore not a standard Pigouvian tax.

<sup>15</sup>107,000 domestic, 94,000 regional flights, plus 21,000 general aviation and military flights, versus 43,000 international movements for the fiscal year 1996-1997.

<sup>16</sup>A related, although different, issue is the possibility to correct externalities through taxes on or subsidies to related goods or production processes (see e.g. Wijkander 1985).

7. Sydney KSA is, so far, the only airport in Australia to face the NLC. Because airlines operate on a spatial network, there is a need for cooperation among the different airports in the country, and maybe harmonization of the tax (at the national and sometimes international level). Otherwise, there is a potential for introducing discriminatory measures that distort competition and resource allocation. In fact, one potential operational effect of a locally-based NLC is for an airline to divert its noisiest aircraft to other routes of its network where the noise restrictions are less stringent and/or where the financial penalty is more accommodating. Note that from an economic point of view such an outcome could be acceptable if the external costs related to aircraft operations are lower elsewhere, a situation that could potentially arise in Australia (see Table 8).

## 6 Impacts on Aircraft Operators and on its Customers

Major Australian airlines (Qantas and Ansett) have upgraded and have expanded their fleets during the 90s, and today their fleets, by and large, comply with the highest noise standards (although Ansett still operated three (Chapter 2) F-28 in June 1998, see Table 13). The mandatory phase-out of Chapter 2 aircraft coupled, to a lesser extent, with a higher NLC for Chapter 2 aircraft, has induced Australian airlines to rapidly withdraw Chapter 2 aircraft from Sydney. Because the NLC *per* passenger is significantly larger for smaller Chapter 2 aircraft, mainly F-28 and B-727, there has certainly been a stronger incentive to phase-out these particular types of aircraft. However, we strongly believe that the main force driving the withdrawal of some Chapter 2 aircraft is the compliance with federal and international laws and the completion of the aircraft life cycle, rather than the additional NLC. Industry sources suggest the effect has been the withdrawal on one aircraft type, namely the F-28.

Insert Figure 13 about here.

For aircraft operators, the direct effect of the NLC is an increase in airport-related charges (part of the operating costs), and therefore a monetary transfer to the airport or the government authorities. Because both domestic and international Australian airline markets are highly duopolistic, and demand for air transportation is fairly inelastic, airlines are more likely to (directly) pass a substantial fraction of the NLC on passengers. In fact, a noise charge of Aus\$ 3.40 *per* passenger is automatically being imposed by individual airlines at their discretion to recover the costs they incur in paying the NLC at Sydney KSA (FAC, 1996). This charge applies to every domestic/regional and international passenger landing at Sydney KSA. With more than 10 million passengers inbound

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new standards must be devised and implemented in order to curb total noise levels. So far, however, ICAO and its Committee on Aviation Environmental Protection (CAEP), although recognizing that new noise certification standards need to be developed that properly take account of technological progress, are unable to reach a consensus on any specific proposal to introduce a new noise standard (ICAO, 1998c).



have that about 48 to 193 international flights, and about 274 to 2,105 domestic/regional flights might not be annually scheduled at Sydney KSA as a result of the NLC. In the total, around 322 to 2,298 flight movements could be annually diverted from Sydney KSA (between 0.132-0.943% of actual movements). Although these effects are small, and other factors like exchange rates, avgas price, and domestic and international economic growth are more likely to influence the future trend of the air transport demand at Sydney KSA, our analysis indicates that depending on the price elasticities estimates, and on the amount of the NLC, the total number of aircraft movements may be curbed at Sydney KSA under a regime of NLC.

Table 14 summarizes the likely impacts on demand and on aircraft movements, had airlines imposed a *per* passenger noise charge of Aus\$ 6.80 or Aus\$ 10.20 instead of Aus\$ 3.40. Such an increase in the noise charge would have occurred had the actual LUR been set higher, as suggested by some local community advocates<sup>25</sup>. The results of Table 14 suggest that, when the price elasticity is valued at its high range, a reduction of around 3% of annual aircraft movements could arise under a *per* passenger noise charge of Aus\$ 10.20. All in all, these results show that the airline industry indirectly bears some of the social costs associated with this mode of transportation in the form of a loss of potential passenger revenues. Similarly, some airport-related charges are forgone for Sydney KSA.

Insert Table 14 here.

## 7 Impacts and Distributional Consequences of Aircraft Noise

### 7.1 Before the Long Term Operating Plan of March 1996

Given aircraft types and aircraft noise characteristics, the allocation of aircraft to flight paths<sup>26</sup> ultimately determines the noise exposure of residents surrounding the airport. With the opening of the third runway [16L-34R] air traffic control had more flight path options (diversification argument) available with Sydney's airspace. However, the Labor Government in its determination on the third runway EIS imposed an operational restriction that there would be no take-offs to the north from the new runway because of noise impacts on residents to the north. In early 1995, the runways available at Sydney KSA were as follows (see Figure 1):

- Arrivals: 07-25, 16R-34L, and 16L-34R.

<sup>25</sup>Indeed, they argued that a higher LUR would have raised additional revenue for the noise mitigation scheme, as well as providing a stronger incentive to operate more noise-efficient aircraft.

<sup>26</sup>Which is the responsibility of air traffic controllers of AirServices Australia.

airport (Marrickville, Leichhardt, Ashfield, Drummoyne, Hunters Hill, Lane Cove, and Ryde). Parts of those suburbs to the east and west of the airport – Botany, Randwick, Rockdale, Kogarah, and Hurstville – obtained a net gain in value of some Aus\$ 200 million from aircraft noise reductions (Kinhill Engineers, Table 23.13, p.23-31, 1990).

In February 1995, soon after operations on the third runway brought home the redistribution of aircraft noise and after consultation with community groups, the Australian Democrats (the third major political party in Australia) decided to push for a Senate Inquiry into Sydney's aircraft noise problems. The press release by New South Wales Senator Vicki Bourne (28 February 1995) said a public inquiry was essential given the "anger and distress" caused by the opening of the third (parallel) runway. The Select Committee on Aircraft Noise in Sydney inquired, among other matters, into: the human impact of noise caused by aircraft movements following the opening of the third runway; reasons for discrepancies between the predicted and actual noise impacts (and proposals to prevent any such discrepancies occurring in the future); the likely effectiveness of the environmental management plans for Sydney KSA (and whether there are other potentially, effective measures, which could be implemented); and the potential for operations at the future Sydney West Airport (SWA) at Badgerys Creek to alleviate the impact of aircraft noise on "Sydney basin communities" (Commonwealth of Australia, p.3, 1995).

The Select Committee on Aircraft Noise in Sydney made comments critical of the environmental assessment of the third runway, and made recommendations on the operational measures implemented to reduce noise at Sydney KSA. One of the main recommendations was the introduction of a legislative cap on annual movements at Sydney KSA, and 80 aircraft movements *per hour* is now Government policy.

## 7.2 Since the Long-Term Operating Plan of 1996

On March 2, 1996, the Liberal/National Coalition won the Federal election (defeating the Labor Party) with a landslide victory in the House of Representatives<sup>29</sup>. The *Sydney Morning Herald*, on the day of the election, summed up what each party had to offer on Sydney KSA and on the future SWA at Badgerys Creek. The incoming government's election policy is reproduced in Table 17.

Insert Table 17 here.

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conducted for Sydney KSA. The most cited studies (Abelson, 1977, and the Draft EIS, 1990) used a hedonic pricing method to identify the implicit price attached to different variables by the house buyer. The Draft EIS study (1990) sampled 344 houses in Botany, Marrickville and Rockdale and compared prices in noise-affected areas with comparable prices that were not noise affected. The most recent study by JLV Research and Consultancy Pty Ltd (Mitchell McCotter, 1994b, Appendix J), sampled 750 property transactions in 1991 and 1992 along the north-south flight path and compared prices with nearby non-noise affected properties. Negative premiums (depreciation rates) in these latter two studies of the northern suburbs are summarized in Table 16.

<sup>29</sup>In the Senate (Upper House), the Democrats, with 5 seats continued to hold the balance of power.

West runway monthly complaints climbed steeply to 6,5000 in July 1996 (Stage I of the LTOP). Departures for the first time of runway 34R (see Figure 1) prompted 8,000 complaints for the month of November 1996. Complaints fell rapidly, and by November 1997 about 2,500 monthly complaints were received. Implementation of Stage II of the LTOP in December 1997 pushed monthly complaints past 9,000. Finally, the most recent data (October 1998) indicate that the number of monthly complaints stabilized at about 3,400 complaints (from 612 complainants). Table 18 illustrates the distribution of aircraft movements according to the cardinal points: (1) before the construction of the third runway (Pre-Parallels, 1993); (2) after the construction of the third runway under the Labour Government (Parallels, 1995); (3) after the construction of the third runway under the Coalition Government (Stage I of the LTOP, end of 1996); (4) Stage II of the LTOP (Oct. 1998), and finally; (5) under the long-term Coalition Government's target for the LTOP.

Insert Table 18 here.

Although it is too early to provide a comprehensive economic, operational and environmental assessment of the LTOP, the concept of noise sharing through a safe and efficient use of different operating modes of all runways is theoretically appealing. In fact, under specific circumstances public choice theory has a strong argument in favour of 'externality distribution'. Assuming that the marginal external cost (MEC) associated with aircraft noise is increasing<sup>33</sup> in the number of aircraft movements *per* runway (N), it is easy to show that total external costs are lower when aircraft movements are distributed over a larger number of runways. Let us consider the following graphical example. Figure 2 displays a linear (increasing) relationship between the number of aircraft movements *per* runway and the marginal external cost, i.e.,  $MEC = a + b \cdot N$ , with  $a \geq 0$ , and<sup>34</sup>  $b > 0$ . First, assume that all the runways have identical characteristics, and that a total of 120 aircraft movements (*per* time unit) are equally shared among two runways (a situation which would depict the 'Parallels' regime in 1995). Since total external costs correspond to twice the area under the MEC of Figure 2, it is easy to show that total external costs correspond to  $3,600 \cdot b$ . Now, let us assume that the same total of 120 movements are equally shared among the three runways (a situation which would rather represent the LTOP's target). A straightforward computation shows that total external costs are reduced to  $2,400 \cdot b$ , all else equal. In other words, when the marginal external cost *per* runway is rising, sharing the traffic over more runways can be

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a survey of 3,575 Australian residents (Hede and Bullen, 1982). Fear of aircraft crashing, personality, socio-economic status and media focus are factors that influence whether annoyance from aircraft is reported.

<sup>33</sup>This is a standard assumption in environmental economics, and it is most likely to apply in the case at hand, although it is ultimately an empirical question. The dramatic surge in the number of noise complaints after the opening of the third runway certainly supports the standard assumption of increasing marginal external costs.

<sup>34</sup>For simplicity's sake, and without loss of generality, we can set  $a=0$ , as in Figure 2.

from the noise levy, if there is a desire to fully apply the Polluter Pays Principle<sup>35</sup>.

In an ideal world, one would aim at comprehensively addressing (i.e. internalizing) the full environmental costs as well as benefits associated with aircraft operations. Such an economic 'first best' would be rather difficult to achieve given the complexity of the problem at hand (uncertainties, multiple constraints, etc.). The Polluter Pays Principle applied in Sydney KSA can be described as a 'n-th best' given the different constraints. To the best of our knowledge, whether sufficient static and dynamic efficiency (i.e., incentive to reduce aircraft noise externalities) is achieved under the current scheme is difficult to assess. Similarly, even if efficiency is achieved under the current scheme, local/regional economic optimality does not necessarily imply global optimality. The fact that the scheme chosen at Sydney KSA combines 'user charges' (i.e., Polluter Pays Principle) and some degree of 'internalization' seems to us appealing in the case at hand (i.e. in the very contentious and complex context of an airport).

The main contribution and originality of this paper is the integration of the various aspects and dynamics driving the economics of air transport in relation to airport infrastructure and operations and the associated environmental externalities. For a number of reasons (e.g. availability of data, transparency, originality of the scheme, etc.) Sydney KSA provides a unique framework for analyzing this complex issue. On the other hand, by focusing on the specifics of Sydney KSA, we are able to discuss broader principles and policy issues likely to be relevant for other major airports around the world.

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<sup>35</sup>It is interesting to note that the principle of an emission-related charge, although not yet fully endorsed by ICAO, has recently gained some favourable ground among the international aviation community (ICAO, 1998c).

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## 10 Appendix

Table 1: Recent Key Dates and Events for the Australian Airline Industry

Date	Events
1952	Introduction of the Two-Airline Policy: This is a legislation to limit 'uneconomic' (i.e., destructive) competition between the two domestic airlines, the publicly owned Trans Australia Airlines (TAA), and the private Australian National Airways (ANA).
1957	Private Ansett (then a regional airline) takes over ANA and forms a new airline Ansett-ANA, which was later renamed Ansett Airlines.
Late 1989	Pilots' dispute affecting the Australian domestic market. Traffic decline by approx. 20% in 1990.
Nov. 1990	End of the Two-Airline Policy. The Australian domestic market is completely deregulated.
Feb. 1992	Merger between publicly owned Qantas and Australian Airlines (AA) (ex-TAA renamed in 1986). The new Qantas becomes the only major operator at that time with both a domestic and an international network. Government adopts the principle of multiple designation in international air services agreements. This enables Ansett Australia to launch its international operations in Sept. 1993, while Qantas loses its status as sole designated flag-carrier.
Mar. 1993	Government sells to British Airways a 25% stake in Qantas. Subsequently, both airlines form a strategic alliance.
Nov. 1994	Inauguration of the third runway at Sydney KSA.
Jan. 1995	Mandatory phase-out of Chapter 2 aircraft to be completed by April 2002.
Jul. 1995	Government sells to the public its remaining 75% of equity in Qantas, thereby becoming fully privatized.
Oct. 96	Private Air New Zealand purchases a 50% stake in Ansett Australia from TNT Corporation.
Nov. 96	Creation of a Single (Trans-Tasman) Aviation Market between Australia and New Zealand.
Jul. 1997	Government sells 'Phase I' airports (Brisbane, Melbourne, and Perth) for long term lease.
Jun. 1998	Government sells 15 'Phase II' airports (Adelaide, Canberra, Coolangatta, and Hobart are among the largest airports) for long term lease.

*Source:* Various including, *inter alia*, Findlay (1996), Hooper and Findlay (1997) and, Forsyth (1998a).

Table 4: Top 20 Australian Airline City-Pair Markets for Fiscal Years 1991 and 1998  
(Ending on June 30)

City-pair	km	Mvts 91	Mvts 98	Pax 91	Pax 98	Seats 91	Seats 98
Melbourne-Sydney	706	23,665	34,440	2,725,931	4,896,388	3,913,527	6,652,701
Brisbane-Sydney	753	16,391	24,145	1,860,103	3,043,136	2,585,579	4,252,983
Brisbane-Melbourne	1,381	6,601	15,728	630,154	1,657,961	818,742	2,060,396
Adelaide-Melbourne	643	9,049	13,752	890,668	1,300,129	1,214,190	1,768,883
Coolangatta-Sydney	680	8,760	11,379	710,727	1,275,881	942,497	1,656,988
Adelaide-Sydney	1,167	5,633	11,470	528,836	1,076,516	707,038	1,460,673
Brisbane-Cairns	1,391	4,677	9,037	408,567	958,401	552,592	1,393,025
Perth-Sydney	3,284	3,185	7,164	335,695	916,627	492,759	1,193,525
Melbourne-Perth	2,706	4,771	6,914	516,096	849,228	704,116	1,062,864
Canberra-Sydney	236	9,727	22,168	562,651	830,576	953,665	1,322,573
Hobart-Melbourne	618	5,817	6,621	478,377	748,129	660,030	910,133
Canberra-Melbourne	470	7,108	9,486	443,271	695,580	743,748	1,080,093
Cairns-Sydney	1,971	1,135	4,857	131,495	644,881	166,951	940,060
Melbourne-Coolangatta	1,330	2,728	4,408	258,497	545,722	335,026	699,644
Brisbane-Townsville	1,112	4,352	4,760	337,829	448,111	483,465	589,620
Lauceston-Melbourne	476	6,312	5,890	325,168	444,652	470,495	548,276
Adelaide-Perth	2,120	2,723	4,316	248,777	405,876	339,490	555,234
Brisbane-Rockhampton	518	2,907	5,593	176,915	243,644	273,468	402,053
Brisbane-Mackay	797	1,713	3,983	91,287	223,619	142,407	332,272
Kalgoorlie-Perth	538	1,453	4,030	89,490	190,527	106,107	318,607
Total		129,107	210,061	11,750,474	21,307,584	16,605,892	29,200,601

Source: BTCE, 1995a, and DTRD, 1998a.

Table 5: Summary Statistics for Top 20 City-Pairs 1991-98, Weighted Average by Group of City-Pairs

City-pair Group	SL(km) 1998	Mvts 91-98 % Growth	Pax 91-98 % Growth	Seats 91-98 % Growth	LF 1991	LF 1998	AS 1991	AS 1998
Total Top 20	1,039	+75.5%	+93.2%	+91.8%	70.8%	73.0%	135	152
Sydney Only (7)	962	+79.1%	+98.3%	+96.0%	70.2%	72.6%	147	167
Others Except Sydney (13)	1,155	+71.1%	+85.7%	+85.6%	71.5%	73.6%	117	129

Source: BTCE, 1995a, and DTRD, 1998a.

Notes: SL=Stage Length, Mvts=Movements, Pax=Passengers, LF=Load Factor, AS=Aircraft Size.

Table 8: Approximate Populations (Private Dwellings) Exposed to Aircraft Noise as Measured by Australian Noise Exposure Index [ANEI], 1990/91

City	ANEI		
	20-25	25-30	30+
Sydney*	45,000	15,000	9,000
Adelaide	14,500	7,400	4,100
Melbourne	14,900	1,700	300

*Source:* Federal Airports Corporation, personal communication; AirServices Australia, 1997, p.100.

*Note:* \*In 1995 the corresponding numbers for Sydney are: 68,400; 29,300; and 11,000.

Table 9: Annual Practical Capacity versus Actual Movements (including General Aviation) at Sydney KSA (100s)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	2003
Practical Capacity	2680	2680	2680	2680	2680	3530	3530	3530	3530	3530
Actual Movements	1580	1850	2030	2220	2270	2420	2560	2640	2640	3300

*Source:* Various, including DTRD, 1998a, BTCE, 1994. Mitchell Cotter, Table 2.1, p.2.9, 1994b. Projections for the year 2003 from the LTOP (1996) assuming 4.1% increase per year.

Table 10: Evolution of Revenue Collected from Aircraft Operators and Expenditure for Noise Mitigation Scheme (in million of Aus\$). Fiscal Year Ending in June.

	Expenditure	Revenue
1994-95	Aus\$ 24.2	—
1995-96	Aus\$ 62.3	Aus\$ 22.1
1996-97	Aus\$ 49.0	Aus\$ 38.7
1997-98	Aus\$ 68.4	Aus\$ 39.4

*Source:* Personal communication with senior officer (Harry Carroll) at AirServices Australia and DTRD, 1998b.



Table 13: Major Australian Airline Fleets (Including Regional Subsidiaries), June 98

Aircraft Type	Qantas	Ansett
B-747*	31	3
B-767*	26	13
B-737*	38	22
A-300*	4	-
A-320*	-	19
BAe146*	14	11
F-28*	-	3
DHC-8*	16	-
DHC-6*	5	-
BA-JS31	4	-
Shorls SD360	7	-
Cessna C-404 Titan	2	-
Total	147	71

Source: Airlines annual reports, 1998.

Notes: \*All types included.

Table 14: Effects on Demand and on Aircraft Movements from Different Noise Charges

Type of market	Reduction in demand from a per pax charge of:			Reduction in aircraft movement from a per pax charge of:		
	Aus\$ 3.40	Aus\$ 6.80	Aus\$ 10.20	Aus\$3.40	Aus\$ 6.80	Aus\$ 10.20
International	7,500-30,300	15,210-60,770	22,780-91,120	48-193	97-387	145-580
Domestic + Regional	28,500-219,000	57,120-437,920	85,680-636,880	274-2,105	549-4,211	824- 6,316
Total	36,000-249,300	72,330-498,690	108,460-748,000	322-2,298	596-4,598	969-6,896

Note: Calculations are based on price elasticities ranging from 0.5-2.0 and from 0.3-2.3, and on a 'representative' round-trip air fare of Aus\$ 1500 and Aus\$ 500, for international and domestic markets respectively.

Table 15: Number of Occupied Private Dwelling Types in the 20 ANEF and Above Contours for the Base Case (1988) and the Long Term (2010) Parallel Runway Operations

Location Relative to Airport	1988	2010	% Change
North	23,158	33,398	+44.2
South	1,071	1,236	+15.4
East	23,384	1,445	-93.8
West	24,326	1,683	-93.1
Total	71,939	37,762	-47.5

Source: Based on Kihill Engineers, Table 23.9, p.23-22, 1990.

Figure 1: Sydney KSA Runways System

